MANGROVE PALYNOLOGY

by

G. THANIKAIMONI

Published by

UNDP/UNESCO Regional Project on Training and Research

on Mangrove Ecosystems, RAS/79/002, and the French Institute, Pondicherry

INSTITUT FRANÇAIS DE PONDICHÉRY

Travaux de la Section Scientifique et Technique

Tome XXIV

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Ganapathi THANIKAIMONI

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PREFACE

Within the guiding principles of the UNDP/UNESCO Regional Project on Training and Research of Mangrove Ecosystems, RAS/79/002, it was considered important to take a look at the palaeoecology of mangroves, as one more factor to help in the understanding of the structure and dynamics of present day mangroves.

This Manual was born from the necessity of adding new dimensions to the study of mangroves for a better management of this life sustaining ecosystem and for its perpetuation as an instrument of production.

We are grateful to Dr. B.S. Venkatachala of the Birbal Sahni Institute of Palaeobotany, Lucknow, who gave us the name of Dr. G. Thanikaimoni. The latter had plunged wholeheartedly in the study of the mangroves of the past, using palynology as a tool and during his unfortunately brief association with the project, he gave us all the benefit of his vast knowledge of both palynology and mangroves, and the benefit of his contagious and invaluable enthusiasm for an important work through his rich and generous personality. We had hoped for a very long association with him, but destiny decided otherwise and Dr. Thanikaimoni fell victim to international terrorism on his flight from Pondicherry to Woods Hole (U.S.A.) where he was to attend the 2nd International Conference on Palaeoceanography.

We are most grateful to Drs. C. Caratini, C. Tissot and Mrs K. Thanikaimoni who readily and generously accepted the difficult task of putting together Dr. Thanikaimoni's notes and thus bringing to a good and quick conclusion the Manual, for the preparation of which Dr. Thanikaimoni had embarked in high spirits, convinced, as he was, that the Manual would not only fill a serious gap in knowledge, but also be very useful for practical purposes.

We hope that the users of the Manual will think likewise.

The final publication of the Manual was made possible by the enthusiastic cooperation extended by the French Institute, Pondicherry, through its Director, Dr. P. Legris and the Deputy Director, Mr. M. Deshayes, to whom we are all deeply indebted.

In conclusion, this Manual is one of the series of publications of the French Institute of Pondicherry and conceptually also an output of the Regional Project on Training and Research of Mangrove Ecosystems RAS/79/002. Two other Manuals are being prepared by the project, one on Hydrological and the other on Microbiological aspects of mangrove ecosystems. The Final Technical Report of RAS/79/002 is a cross section of the present day knowledge of the mangroves of Asia and the Pacific and their management within the framework of COMAR (Coastal and Marine Major Project) of UNESCO.

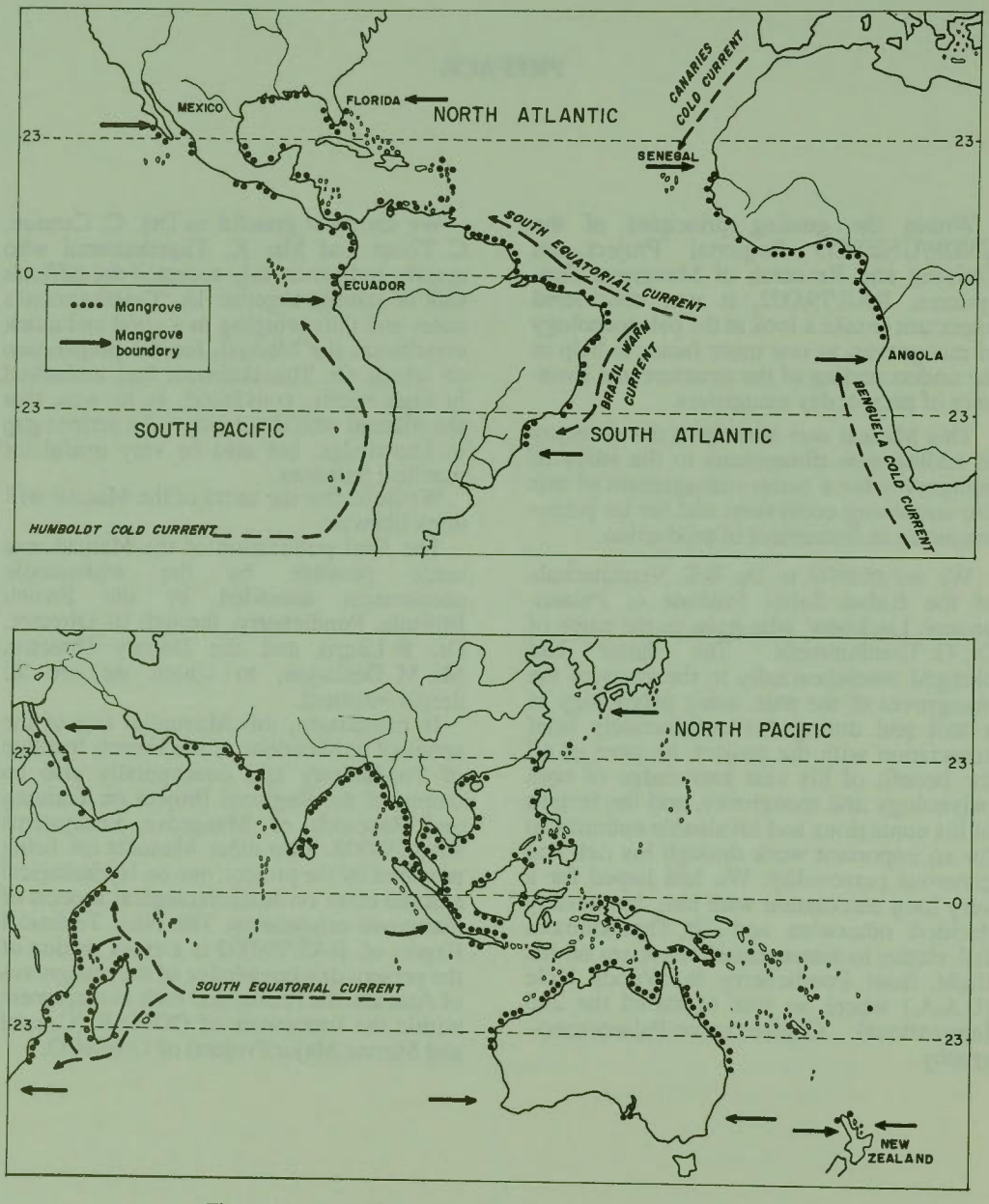

Fig. 1. Recent world mangrove distribution (from Kiener, 1973).

INTRODUCTION

Mangrove ecosystems are among the most characteristic features of the low lying tropical coastlines, and, where environmental conditions are suitable, they extend southwards beyond the tropic of Capricorn and northwards beyond the Tropic of Cancer. The coastal zone everywhere, specially in the tropics, is highly dynamic, being exposed to land/sea/atmospheric interactions and to the interplay of hydrological, geological, meteorological and ecological factors and forces. The mangrove ecosystem represents a unique and irreplaceable adaptation to such a special environment.

Accordingly the condition of any mangrove ecosystem should be considered as the present stage in a long evolutionary history the rate of change of which varies from place to place. Changes are, for instance, very fast in the accretion areas of the delta of large rivers the waters of which carry large sediment loads, or in cyclone prone areas or those affected by volcanism, while they may be very slow in geologically steady coastlines without much change in mean sea level and tidal regime over long periods.

Thus an understanding of the dynamics of the ecosystem can benefit from a study of the past history of different mangroves ; one of the aims of such studies is to try to predict the reaction of mangrove ecosystems to positive or negative changes in mean sea level. Such changes may be brought about by slow or quick geological coastal rising or sinking or by the global atmospheric warming, usually called the green house effect or, eventually by the so called nuclear winter. Another aspect is the assessment of the land building capacity of mangrove ecosystems, this aspect also can benefit from a study of the past history of the mangroves of the same site.

Blasco (1984) emphasized the importance of palynology in the study of present and past mangrove ecosystems and summarized the knowledge to that date.

Palynology is a technique that allows for an analysis of the past history to be made with some precision specially in the coastal zone, because vegetation is the major component of the mangrove ecosystem. Because the vegetation is directly affected by climatic, geographical and geological changes, palynological studies may reveal not only the past extent of mangroves but the changes of environmental conditions over time as well. The establishment of correlations between species composition and extent of mangrove ecosystems over time thus appears to be the most important contribution that palynology can make to the understanding of contemporary mangrove ecosystems, their structure and dynamics, besides its use for oil prospection.

The inventory of the plant species composition from present day mangroves has been published by the National Mangrove Committees of each country, since the floristic species diversity is site specific, however it was deemed interesting to include in this Manual and in the context of palynological studies at large, an updated list of species from mangrove ecosystems that we hope will be of general interest and validity. Although debatable and by no means generally valid, for practical purposes and as a useful approximation, the distinction is made in the text, of "core mangroves" and "peripheral mangroves", where "core mangrove" species include obligatory mangrove ecosystem species that are restricted to the intertidal brackish water zones, such as the genera *Aegiceras, Avicennia, Bruguiera, Ceriops, Kandelia, Lumnitzera, Nypa, Rhizophora, Sonneratia* some of which (e.g. *Avicennia*) are found beyond the tropical belt.

"Peripheral mangrove species", or better designated "non obligatory" mangrove species, are those that are tolerant of a wide range of variation of ecological parameters and are not restricted to the intertidal tropical

zone, such as *Acrostichum spp. Hibiscus tiliaceus* or even *Acanthus ilicifolius*.

Within the spirit of the UNDP/UNESCO Regional Project on Training and Research of Mangrove Ecosystems, RAS/79/002 (1983-1986) and with the purpose of achieving a better understanding of the structure and dynamics of the mangrove ecosystem, we approached Dr. G. Thanikaimoni, a leading palynologist with a deep knowledge of mangroves; together with him and later with Drs. Caratini and Tissot we decided that a marriage between these two branches of ecology, namely palynology and community structure of tropical tidal forests or mangroves, would be fruitful for the development of both disciplines.

The author, and Drs. Caratini and Tissot who finalized the text after the tragic demise of Dr. Thanikaimoni, have endeavoured to prepare a practical manual for the use of scientists interested in palaeoecology as well as in contemporary ecology of tropical coastal systems. Each chapter focuses on different aspects of the palynological study of mangrove ecosystems.

It was considered useful to separate the work done on the Holocene and Pleistocene, from that done on the Tertiary. In fact the studies of the Quaternary can find support on the contemporary flora and on the pollen and spores of the mangrove vegetation. On the other hand, when studying the Tertiary, interpretations are unavoidably less precise; in these cases, pollen and spores of the mangroves are mainly used as stratigraphic or palaeogeographic markers. They are particularly interesting for oil research because pollen and spores from mangroves are frequently associated with sediments rich in organic matter, as are found in tropical deltas.

For what concerns methodologies, reference is made in the text to the specialised papers already published on the matter. The text deals in more detail on points usually untouched by earlier authors that are nevertheless necessary for reaching reliable conclusions on the palynology of mangrove ecosystems. These refer in particular to instruments and techniques for sampling the mangrove muds.

The more detailed part of this manual, because the authors believe it to be the most useful, is the one that refers to the morphology of pollen and spores. Accordingly the pollen of all Angiosperms and the spores of *Acrostichum aureum* one of the few ferns present in mangroves, are illustrated in detail. A key is proposed for their identification.

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in Asia and The Pacific

PALYNOLOGICAL METHODOLOGY

An exhaustive description of the palynological methodology is far beyond the scope of the present work. However some important publications may be mentioned which are necessary for a fair knowledge of palynological methodology.

One of them is the "Textbook of pollen analysis" from Fægri and Iversen (1975). It is desirable for a researcher wanting to deal with palynology to master this work.

Specially written for peat accumulation, this book provides useful data directly applicable to mangrove sediments.

1) *Field technique*

The types of peat borers commonly used for collecting sediments are given in Fægri and Iversen's book with comments on their use, advantages and drawbacks.

De Beaulieu and Reille (1978) have described four kinds of borers with comparative studies of the pollen diagrams obtained by each type.

From this paper, it is obvious that the most commonly used "Hiller" hand peat-borer is not very reliable and should be abandoned. It is preferable to use the "soviet" hand peat-borer. As this device is not available, its diagram is given in figure 2. The borer is made up of two parts:

- the *core chamber*, which is half cylindrical and can be rotated around its axis;
- and the *shutter*, a flat part larger than the chamber. This part stays fixed in the sediment while the chamber rotates around it.

The use of this borer is very simple (Fig. 3). It is driven without rotating into the sediment with the chamber closed by the shutter (A). When the required depth is reached, a 180° clockwise rotation fills the chamber (B). Then, the borer is lifted upright, again without rotating (C). By rotating anticlockwise at 180° the borer (D) and the half cylindrical core can be collected and preserved in a semi-cylindrical plastic pipe without any disturbance or contamination. The core samples can be easily and safely transported in these plastic pipes.

In the tropics, it is advisable to poison the core samples with phenol to prevent the growth of fungi and/or bacteria in them.

For proper collection of samples in the field, it is necessary to make two borewells a few meters away from each other. One of them is systematically studied while the other is kept as a reference and studied only when the results obtained from the first one have to be checked or confirmed. It is essential to dig two holes in each borewell to avoid the collection of samples being disturbed by the base of the corer (Fig. 4).

2) *Laboratory technique*

The identification of fossil pollen is well developed in the "Textbook of pollen analysis". The *sample processing* as well as the indispensable "*pollen herbarium*", i.e. the collection of modern spores and pollen grains, are clearly explained in it.

The identification of fossil pollen grain is based on comparison of their morphological characters with those of the modern plants. This is the only method which ensures a certain degree of accuracy. Although an iconographical survey is useful in the early stages of investigation, the results obtained are not always reliable.

Another work which provides information on palynological preparatory techniques is that of Gray (1965). It gives a comprehensive account of physical and chemical techniques in addition to extensive references to earlier pertinent literature. Gray has stressed the need for an individualistic approach to sample processing whereby due regard is given to lithological characteristics; there is no one method of processing but a general protocole which has to be adapted to the particular characteristics of the current samples. Gray also insists on the desirability of successive monitoring of the residue at each step of process.

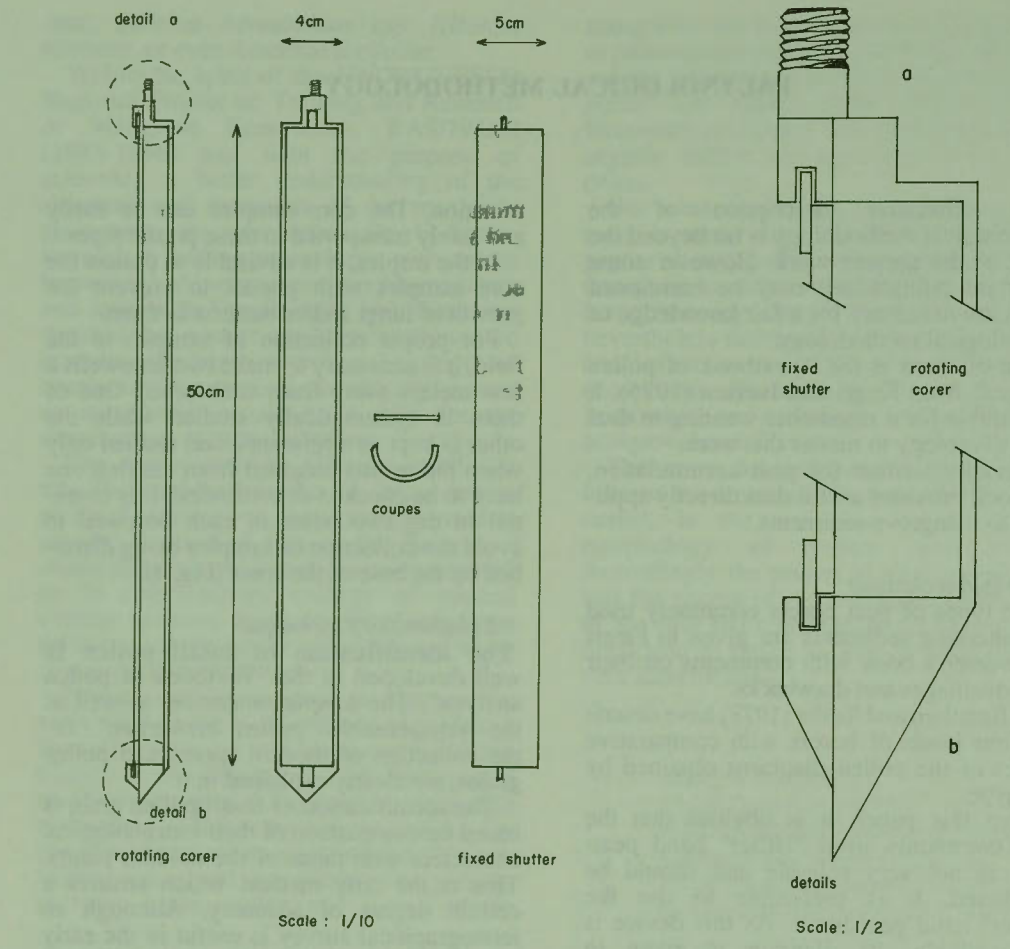


Fig. 2. Diagram of the "soviet" borer.

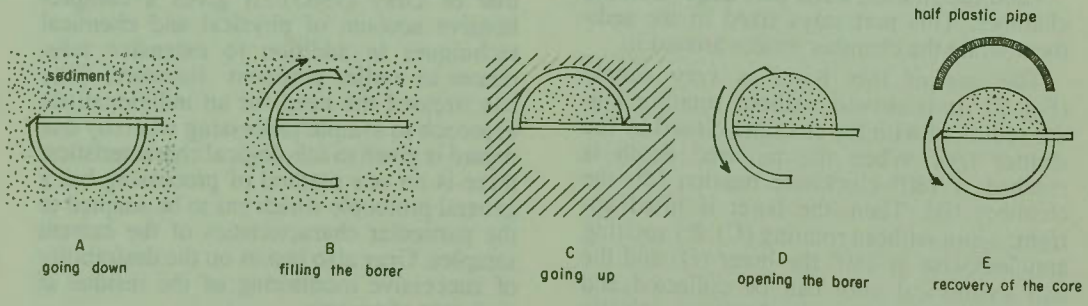


Fig. 3. Use of the "soviet" borer.

Ultrasonic sieving is a new device (Caratini, 1980) currently used in many laboratories to improve palynological processing of sediments. The advantages of this method are:

- maximum concentration of palynomorphs;
- clean slides with palynomorphs free of minute particles;
- quick preparation of samples.

3) *Pollen diagrams and interpretation*

The principles to be followed for pollen analysis and plotting of pollen diagrams have been dealt with in detail by Fægri and Iversen (op. cited).

New developments in data handling and computerization in recent years have considerably increased the approaches to their interpretation. For example, Tucker and Tucker (1985) article gives an idea of what could be achieved by computers.

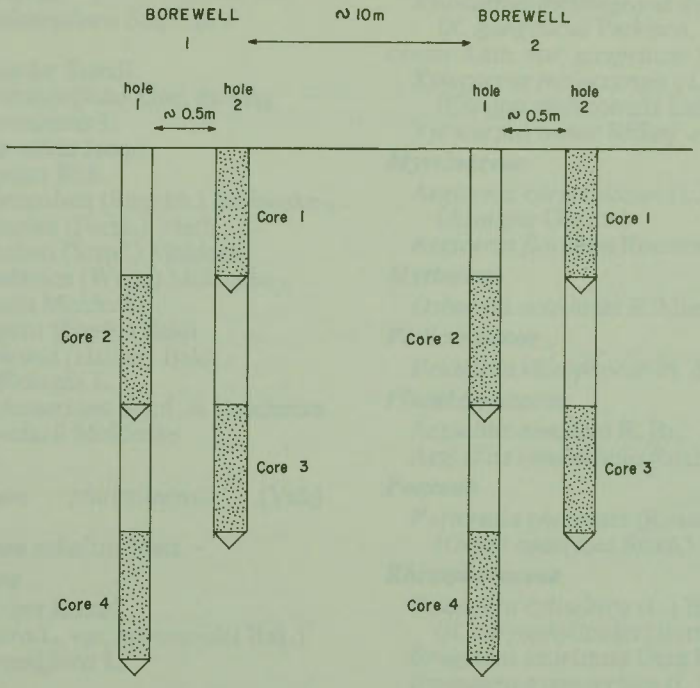
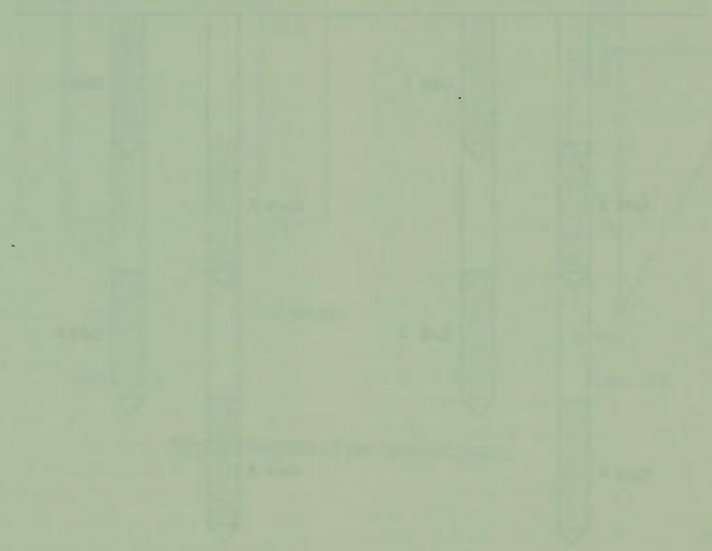


Fig. 4. Technique of coring. Samples from Borewell 1 are for studies; cores from Borewell 2 are stored as reference material.



MANGROVE SPECIES OF THE WORLD[1]

Core Mangrove

Arecaceae

Nypa fruticans Wurmb.
Phoenix paludosa Roxb.

Avicenniaceae

Avicennia africana P. Beauv.
Avicennia alba Bl.
Avicennia balanophora Stapf. & Moldenke
Avicennia bicolor Standl.
Avicennia eucalyptifolia Zipp. ex Miq.
Avicennia germinans L.
(*Avicennia nitida* Jacq.)
Avicennia lanata Ridl.
Avicennia lanceolata (Engelth.) Moldenke
Avicennia marina (Forsk.) Vierh.
var. acutissima (Stapf.) Moldenke
var. australasica (Walp.) Moldenke
var. anomala Moldenke
var. resinifera (Forsk.) Bakh.
var. rumphiana (Hallier) Bakh.
Avicennia officinalis L.
Avicennia schaueriana Stapf. & Leechman
Avicennia tonduzii Moldenke

Bombacaceae

Camptostemon philippinensis (Vid.) Becc.
Camptostemon schultzii Mast.

Caesalpiniaceae

Cynometra iripa Kostel.
(*C. ramiflora* L. var. *mimosoides* Bak.)
Cynometra ramiflora L.

Combretaceae

Conocarpus erectus L.
Laguncularia racemosa (L.) Gaertn. f.
Lumnitzera littorea (Jack) Voight
(*L. coccinea* Wt. & Arn.)
Lumnitzera racemosa Willd.

Euphorbiaceae

Excoecaria agallocha L.

Meliaceae

Xylocarpus australasicus Ridley
Xylocarpus benadinensis Mattei
Xylocarpus granatum Koenig
(*Carapa obovata* Bl.)
Xylocarpus mekongensis Pierre
(*X. gangeticus* Parkison, *Carapa moluccensis* Lam. *var. gangeticus*)
Xylocarpus moluccensis (Lam.) Roem.
(*Carapa moluccensis* Lam.)
Xylocarpus minor Ridley

Myrsinaceae

Aegiceras corniculatum (L.) Blanco
(*A. majus* Gaertn.)
Aegiceras floridum Roemer & Schultes

Myrtaceae

Osbornia octodonta F. Muell.

Pelliceriaceae

Pelliciera rhizophorae Pl. & Tr.

Plumbaginaceae

Aegialitis annulata R. Br.
Aegialitis rotundifolia Roxb.

Poaceae

Porteresia coarctata (Roxb.) Takeoka
(*Oryza coarctata* Roxb.)

Rhizophoraceae

Bruguiera cylindrica (L.) Bl.
(*B. caryophylloides* (Burm. f.) Bl.)
Bruguiera exaristata Ding Hou
Bruguiera gymnorrhiza (L.) Lam.
(*B. conjugata* Merr.)
Bruguiera hainesii C.G. Rogers
Bruguiera parviflora (Roxb.) Wt. & Arn. ex Griff.
Bruguiera sexangula (Lour.) Poiret
(*B. eriopetala* Wt. & Arn.)
Ceriops decandra (Griff.) Ding Hou
(*C. roxburghiana* Arn.)

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[1] Other lists of mangrove species are to be found in V.J. Chapman (1976), H. Barth (1982), P. Saenger *et al.* (1983), F. Blasco (1984) or R. Mephan and J. Mephan (1985).

Ceriops tagal (Perrottet) C. B. Robinson
(*C. candolleana* Arn.)
Kandelia candel (L.) Druce
(*K. rheedii* Wt. & Arn.)
Rhizophora apiculata Bl.
(*R. candelaria* DC.)
Rhizophora harrisonii Leechman
Rhizophora lamarckii Montrouzier
Rhizophora mangle L.
Rhizophora mucronata Lam.
Rhizophora racemosa G. Meyer
Rhizophora stylosa Griff.
(*R. mucronata* Lam. *var. stylosa* (Griff.) Schimper)

Rubiaceae

Scyphiphora hydrophyllacea Gaertn.

Sonneratiaceae

Sonneratia alba J.E. Smith
Sonneratia apetala Buch.-Ham.
Sonneratia caseolaris (L.) Engl.
(*S. acida* L.)
Sonneratia griffithii Kurz
(*S. acida* L. var. *griffithii* Kurz)
Sonneratia ovata Baker
Hybrids:
Sonneratia alba x *caseolaris*
Sonneratia alba x *ovata*

Sterculiaceae

Heritiera fomes Buch.-Ham.
(*H. minor* Roxb.)
Heritiera littoralis Aiton ex Dryander

Peripheral mangrove species (often or occasionally recruited) from fresh water swamps, salt marshes and strand flora

Acanthaceae

Acanthus ebracteatus Vahl.
Acanthus ilicifolius L.
Acanthus volubilis Wall.

Aizoaceae

Sesuvium portulacastrum L.

Arecaceae

Mauritia flexuosa L. f.
Oncosperma tigillarium (Jack) Ridley
(*O. filamentosum* Bl.)

Barringtoniaceae

Barringtonia asiatica (L.) Kurz
Barringtonia racemosa Roxb.

Bignoniaceae

Dolichandrone spathacea (L. f.) K. Schum.

Blechnaceae

Stenochlaena palustris (Burm.) Bedd.

Caesalpiniaceae

Caesalpinia crista L.
(*C. nuga* L.)
Intsia bijuga (Colebr.) Ktze.
(*I. retusa* (Colebr.) Kurz)
(*Afzelia retusa* Kurz)

Chenopodiaceae

Atriplex stocksii Boiss.
Halosarcia indica (Willd.) P.G. Wilson
(*Arthrocnemum indicum* (Willd.) Moq.)
Salicornia brachiata Roxb.
Salsola foetida Del.
Salsola kali L.
Suaeda fruticosa Forsk.
Suaeda maritima (L.) Dum.
Suaeda monoica Forsk.
Suaeda nudiflora Moq.

Clusiaceae

Symphonia globulifera L. f

Convolvulaceae

Ipomoea macrantha Roemer & Schultes
(*I. tuba* (Schlecht.) Don)
Stictocardia tiliifolia (Desr.) Hallier f.

Flagellariaceae

Flagellaria indica L.

Loranthaceae

Dendrophthoe falcata (L. f.) Etting.

Lythraceae

Pemphis acidula J.R. & G. Frost.

Malvaceae

Hibiscus tiliaceus L.

Meliaceae

Aglaia cucullata
(*Amoora cucullata* Roxb.)

Mimosaceae

Prosopis chilensis (Mol.) Stuntz

Myrtaceae

Melaleuca leucodendron L.

Papilionaceae

Dalbergia horrida (Dennst.) Mabberley (*D. spinosa* Roxb.)

Derris heterophylla (Willd.) Back. (*D.trifoliata* Loen., *D. uliginosa* Benth.)

Poaceae

Myriostachya wightiana (Nees ex Stendel) Hook. f.

Pteridaceae

Acrostichum aureum L.

Salvadoraceae

Azima tetracantha Lam.

Salvadora persica L.

Solanaceae

Solanum trilobatum L.

Tiliaceae

Brownlowia argentata Kurz

Brownlowia elata Roxb.

Brownlowia tersa (L.) Kosterm. (*B. lanceolata* Benth.)

Taxodiaceae

Taxodium distichum (L.) Rich.

Verbenaceae

Clerodendrum inerme Gaertn.

SPECIES AND SPECIMENS EXAMINED

The abbrevations used for the herbaria are in accordance with Holmgren & Keuken's Index Herbarium:

BO = BOGOR (Indonesia): Herbarium Bogoriense.
BSI = POONA (India): Botanical Survey of India.
CAL = CALCUTTA (India): Botanical Survey of India, Head office, Central National Herbarium.
DD = DEHRA DUN (India): Forest Research Institute and Colleges.
G = GENEVE (Switzerland): Conservatoire et Jardin Botaniques.
HIFP = PONDICHERRY (India): Institut Français.
K = KEW (Great Britain): Royal Botanical Gardens.
L = LEIDEN (Netherlands): Rijksherbarium.
M = MUNCHEN (Federal Republic of Germany): Botanische Staatssammlung.
MH = COIMBATORE (India): Botanical Survey of India.
P = PARIS (France): Muséum National d'Histoire Naturelle, Laboratoire de Phanérogamie.
PCM = MADRAS (India): Presidency College.
SING = SINGAPORE (Republic of Singapore): Herbarium & Library, Botanic Garden.
TL = TOULOUSE (France): Faculté des Sciences, Laboratoire de Botanique.
US = WASHINGTON (U.S.A.): National Herbarium, Department of Botany.
YA = YAOUNDE (Cameroon): Service des Eaux et Forêts du Cameroun.

Pteridaceae

Acrostichum aureum L., Goa (India), G. Thanikaimoni 1131 – HIFP.

Arecaceae

Phoenix paludosa Roxb., Sundarbans (India), G. Thanikaimoni s.n. – HIFP.
Nypa fruticans Wurmb., Cameroon, Villiers & Caratini 746 –YA.
Nypa fruticans Wurmb., Madras, G. Thanikaimoni s.n. –HIFP.

Acanthaceae

Acanthus ebracteatus Vahl., Brunei, Van Niel 4366, slide IFP 814.
Acanthus ebracteatus Vahl., Singapore, Sainclair s.n. – L.
Acanthus ilicifolius L., Goa (India), K. Naresh Babu 2794 – DD.

Plumbaginaceae

Aegialitis annulata R. Br., Queensland (Australia), Stoddart 4991 – US.
Aegialitis rotundifolia Roxb., Sundarbans (India), G. Thanikaimoni s.n. – HIFP.

Rubiaceae

Scyphiphora hydrophyllacea Gaertn., Singapore, Debeaux 106 – P.

Euphorbiaceae

Excoecaria agallocha L., Goa (India), K. Naresh Babu 2791 – DD.

Rhizophoraceae

Bruguiera cylindrica (L.) Bl., Pichavaram (India), Caratini & Meher-Homji s.n. – HIFP.

Bruguiera exaristata Ding Hou, Queensland (Australia), Stoddart 4785 – US.
Bruguiera gymnorrhiza (L.) Lam., Andaman Islands, K. Thothathri 9054 – MH.
Bruguiera gymnorrhiza (L.) Lam., Nicobar Islands, K. Thothathri 9335 – MH.
Bruguiera gymnorrhiza (L.) Lam., Godavari (India), T. Seshagiri Rao s.n., slide IFP 2483.
Bruguiera hainesii C.G. Rogers, Sundarbans (India), Mukherjee 6245 – CAL.
Bruguiera parviflora (Roxb.) Wt. & Arn. ex Griff., Solomon Islands, L.J. Brass 3108 – G.
Bruguiera sexangula (Lour.) Poiret, Sundarbans (India), Blasco 3041 – TL.
Ceriops decandra (Griff.) Ding Hou, Pichavaram (India), Blasco 10 – HIFP.
Ceriops tagal (Perrottet) C.B. Robinson, Karumbar Islands (India), G. Thanikaimoni 1087 – HIFP.
Ceriops tagal (Perrottet) C.B. Robinson, – PCM.
Kandelia candel (L.) Druce, Orissa (India), G. Thanikaimoni & Caratini s.n. – HIFP.
Rhizophora apiculata Bl., Karwar (India), G. Thanikaimoni 1146 – HIFP.
Rhizophora harrisonii Leechman, Panama, Erlanson 13 – US.
Rhizophora lamarckii Montrouz., Olive River Estuary, N.C.D. Aims 522, slide IFP 21515.
Rhizophora lamarckii Montrouz., Queensland (Australia), W.T. Jones s.n., slide IFP 19339.
Rhizophora x lamarckii Montrouz., Pichavaram (India), G. Thanikaimoni 1783 – HIFP.
Rhizophora mangle L., Guadeloupe, A. Raynal-Roques & Jérémie 2113 – P.
Rhizophora mucronata Lam., Krusadai Islands (India), – PCM.
Rhizophora mucronata Lam., Goa (India), G. Thanikaimoni 1140 – HIFP.
Rhizophora mucronata Lam., Godavari (India), T. Seshagiri Rao s.n., slide IFP 3157.
Rhizophora racemosa G. Meyer, Angola (?), Gossweiler 808 – US.
Rhizophora stylosa Griff., Lamlea Dutch E. India, L.S. Gibbs 6293, slide IFP 15724.

Combretaceae

Conocarpus erectus L., Salvador, Eyerdam 8756 – US.
Laguncularia racemosa Gaertn. f., British Honduras, Spellman & Stoddart 2228 – US.
Lumnitzera littorea (Jack) Voight, Andaman Islands, K. Thothathri s.n. – MH.
Lumnitzera racemosa Willd., Krusadai Islands (India), G. Thanikaimoni s.n. – HIFP.
Lumnitzera racemosa Willd., Godavari (India), T. Seshagiri Rao s.n., slide IFP 3154.

Myrsinaceae

Aegiceras corniculatum (L.) Blanco, Karumbar Islands (India), G. Thanikaimoni 1809 – HIFP.
Aegiceras corniculatum (L.) Blanco, North Kanara (India), – PCM.
Aegiceras floridum Roemer & Schultes, Amboina (Moluccas), C.B. Robinson 253 – P.

Sterculiaceae

Heritiera fomes Buch.–Ham., Orissa (India), L.K. Banerjee 8980 – HIFP.
Heritiera littoralis Aiton ex Dryander, Spiracha Bang Pua, D.J. Collins 1924, slide IFP 15569.

Avicenniaceae

Avicennia africana P. Beauv., Nigeria, W.G. Chaloner s.n. – K.
Avicennia alba Bl., Java, S.H. Koorders 9694 – BO.
Avicennia bicolor Standl., Panama, H. Pittier 4968 – P.
Avicennia eucalyptifolia Zipp. ex Miq., Nesbit River estuary, N.C.D. Aims 534, slide IFP 21514.
Avicennia germinans L., British Guyana, S.G. Harrison 1534 – K.
Avicennia lanata Ridl., Malaya, K.M. Kochummen 77728 – K.
Avicennia lanata Ridl., Malaya, H.M. Burkill 1831 – SING.

Avicennia marina var. *marina* (Forsk.) Vierh., Pichavaram (India), G. Thanikaimoni s.n. – HIFP.
Avicennia marina var. *marina* (Forsk.) Vierh., Queensland (Australia), Flecker s.n., slide IFP 14521.
Avicennia marina var. *acutissima* Stapf. & Mold. ex Mold., Thana (India), G. Thanikaimoni 1121a – HIFP.
Avicennia marina var. *resinifera* (Forsk.) Bakh., Papua, L.J. Brass 882 – BO.
Avicennia marina var. *rumphiana* (H. Hallier) Bakh., Moluccas, Fika-Fika 933 – BO.
Avicennia officinalis L., Pichavaram (India), G. Thanikaimoni s.n. – HIFP.
Avicennia officinalis L., Goa (India), K.C. Kanodia s.n. – BSI.
Avicennia schaueriana Stapf. & Leechman, Brasil, Lützelburg 401 – M.
Avicennia tonduzii Moldenke, Costa Rica, Tonduz 10060 – M.

Caesalpiniaceae

Cynometra ramiflora L., Andaman Islands, K. Thothathri 9121 – MH.

Myrtaceae

Osbornia octodonta F. Muell., Queensland (Australia), Thozet s.n. – P.

Tiliaceae

Brownlowia argentata Kurz, Papua, L.J. Brass 28839 – US.
Brownlowia elata Roxb., Kalimantan (Indonesia), C. Caratini s.n. – HIFP.
Brownlowia tersa (L.) Kosterm., Sundarbans (India) – CAL.

Pelliceriaceae

Pelliciera rhizophorae Planchon & Triana, Panama, Hayes 76 – K.

Bombacaceae

Camptostemon philippinensis (Vid.) Becc., Philippines, L. Escritor 1584 – P.

Meliaceae

Xylocarpus australasicus Ridley, Papua, Hoogland 4302 – US.
Xylocarpus granatum Koenig, Malaya, Diemont & Van Wingaarden 89 – HIFP.
Xylocarpus granatum Koenig, Java – L.
Xylocarpus mekongensis Pierre, Pichavaram (India), Kannan s.n. – HIFP.
Xylocarpus moluccensis (Lam.) Roem., Java, F.C.V. Faber s.n. – M.

Sonneratiaceae

Sonneratia alba J.E. Smith, South Kanara (India), Fyson 5517 – PCM.
Sonneratia alba J.E. Smith, Elephanta Islands (India), G. Thanikaimoni 1122 – HIFP.
Sonneratia alba x *caseolaris*, Brunei, J. Muller 11 – L.
Sonneratia alba x *ovata*, Brunei, J. Muller 8 – L.
Sonneratia griffithii Kurz, Burma, Kermode 7136 – K.
Sonneratia ovata Baker, Singapore, H.N. Ridley 8434 – SING.
Sonneratia ovata Baker, Brunei, J. Muller 7 – L.
Sonneratia caseolaris (L.) Engl., Honnavar (India), G. Thanikaimoni 1817 – HIFP.
Sonneratia apetala Buch.-Ham., Elephanta Islands (India), G. Thanikaimoni 1123 – HIFP.
Sonneratia apetala Buch.-Ham., Godavari (India), – P.

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The following are the definitions of select terms used in this key (see also: APLF, 1975; Faegri & Iversen, 1975; Nilsson & Muller, 1978; Thanikaimoni, 1978).

aperture: morphologically it is an opening or a thinning of exine (except in operculate apertures) where the intine is thickened; physiologically it could be either a germinative zone or a harmomegathus, or both.

apertural membrane: thin exine of the aperture.

colpus (*adj.* colpate): meridional simple aperture having length/breadth ratio > 2.

colporus (*adj.* colporate): meridional composite aperture having an elongated ectoaperture (**colpus**) and an endoaperture (**os**).

columellae (*adj.* columellate): infratectal columnar elements of the sexine.

costae: thickening of the nexine bordering the apertures.

costae colpi: costal thickening accompanying colpus.

costae equatoriales: girdle like costal thickening at the equator.

costae pori: costal thickening accompanying the pore or os.

ectexine: outer layer of exine staining red with fuchsin B and differing from the endexine by electron density as seen in TEM.

ectoaperture: the thinning or opening in the ectexine/sexine.

endexine: inner layer of exine that appears faintly pink after staining with fuchsin B and differing from the ectexine by electron density as seen in TEM.

endoaperture: thinning or opening in the endexine/nexine, also known as os.

endosculpture: sculpture of the inner surface of the nexine or endexine.

equatorial axis: the greatest axis, perpendicular to the polar axis, except when the pollen is constricted at the equator. When the equatorial contour is elliptic or rectangular, two equatorial axes E^1 and E^2 are measured.

exine: external wall of pollen containing sporopollenin.

fastigium (*pl.* fastigia): cavity in a colporate grain caused by a separation or discontinuity of nexine and accompanied by a dome shaped sexine in the area of the endoaperture.

fossula (*adj.* fossulate): ± elongated irregular depressions.

foveola (*adj.* foveolate): ± circular depressions.

heteropolar: pollen grain with asymmetrical distal and proximal parts.

infratectum: situated under the tectum.

intine: part of the pollen wall between the exine and the cytoplasm. It lacks sporopollenin and does not resist acetolysis.

isopolar: pollen grain with ± symmetrical distal and proximal parts.

lumina: meshes of the reticulum.

meridional: surface features perpendicular to the equatorial plane.

nexine: inner exine representing either sole (foot layer), or endexine, or both.

operculum: thickened exine covering the aperture, often getting detached after acetolysis.

os (*pl.* ora; *adj.* orate): nexinal or endexinal part of the composite aperture; also known as endoaperture.

pilum (*pl.* pila, *adj.* pilate): sculptural element consisting of a ± swollen apex and a

rod-like neck.

polar axis: line between the proximal and distal poles.

poles: the two extremities of the axis oriented towards the centre of the tetrad at the time of pollen (and spore) development.

porus or **pore** (*adj.* porate): simple aperture with length/breath ratio < 2. The pores are equatorial in position. When they are distributed over the entire surface of the pollen grain, the latter is described as periporate.

pseudocolpus: symmetrically distributed, elongated exinal thinning or opening resembling the colpus but not associated with an underlying intinal thickening.

reticulum (*adj.* reticulate): net work with walls (muri) encircling the lumina.

rugulae (*adj.* rugulate): irregularly elongated sculptural elements.

scabrae (*adj.* scabrate): sculptural elements of < 1 μm dimension.

sexine: outer, usually sculptured, layer of exine.

spine (*adj.* spiny or echinate): pointed sculptural elements.

sulcus (*adj.* sulcate): distal elongated aperture.

syncolpate: fused colpi.

synorate: fused ora.

tectum: the outer stratum of the sexine found over a columellar or granular stratum; it may be either continuous (imperforate) or discontinuous with perforations (per-reticulate, per-foveolate, per-fossulate). The tectum is either homogeneous (simple) or heterogeneous (structurate).

verrucae (*adj.* verrucate): ± isodiametrical sculptural elements with basal diameter equal to or greater than the height.

KEY TO MANGROVE POLLEN AND SPORES

(Digits between brackets refer to the plate numbers)

1. Heteropolar spore with triradiate tetrad mark	*Acrostichum aureum*	**(1, 2)**
1. Heteropolar pollen, monosulcate, reticulate	*Phoenix paludosa*	**(3)**
1. Isopolar pollen		
2. **meridionosulcate** (with meridional girdle like aperture), spinulate, finely reticulate in between spines, sometimes spines incompletely developed (± wart like); acetolysed and fossil pollen often broken into halves along the aperture	*Nypa fruticans*	**(4)**
2. **tricolpate**		
3. ***reticulate*** with a free columellar element in the lumina, 3 lobed in polar view, acetolysed pollen sometimes broken along the colpus	*Acanthus ebracteatus* *Acanthus ilicifolius*	**(5)** **(5)**
3. ***densely pilate***, nexine honey comb like, aperture membrane operculoid; pollen rarely 2-syncolpate or 6-pericolpate	*Aegialitis annulata* *Aegialitis rotundifolia*	**(6, 7)** **(8, 9)**
2. **tricolporate**		
3. ***without pseudocolpi***		
4. *ectoaperture long* (longicolporate), generally free, pollen longiaxial to equiaxial, sometimes breviaxial, endoaperture perpendicular to the ectoaperture		
5. aperture 3-partite (ectoaperture, mesoaperture and endoaperture), nexine endosculptured, sexine reticulate; pollen rarely disyncolporate.	*Scyphiphora hydrophyllacea*	**(10)**
5. aperture 2-partite (ectoaperture, endoaperture), costae colpi present, costae pori discontinuous at the equator.		
6. fastigiate, ectoaperture constricted at the equator, endoaperture perpendicular to the ectoaperture.		

7. infratectum distinctly columellate, exine reticulate, endoaperture narrowly elliptic	*Excoecaria agallocha*	**(11)**
7. infratectum faintly columellate, exine scabrous to finely reticulate		
8. costae prominent		
9. endoaperture wide, with uneven lateral ends; pollen sometimes tetracolporate or dicolporate; often synorate or nearly so in *Rhizophora sp.*	*Bruguiera spp.* *Ceriops spp.* *Kandelia spp.* *Rhizophora spp.*	**(12)** **(13)** **(14)** **(15-17)**
9. endoaperture broadly elliptic	*Laguncularia racemosa*	**(18)**
9. endoaperture papiliform; rarely tetra-(peri)syncolporate	*Aegiceras corniculatum* *Aegiceras floridum*	**(18)** **(18)**
8. costae feeble, endoaperture elliptic	*Heritiera fomes* *Heritiera littoralis*	**(19)** **(19)**
6. non fastigiate, ectoaperture wide at the equator, endoaperture circular or elliptic (parallel to the ectoaperture)		
7. reticulate, infratectum columellate; costae absent; sometimes dicolporate with ectoapertures free or fusing at poles or 6-pericolporate (dyads?) or inaperturate without content	*Avicennia spp.*	**(20-28)**
7. rugulate-verrucate, rugulae and warts anastomosing, infratectum not distinctly columellate, costae colpi present	*Cynometra ramiflora*	**(29)**
4. *ectoapertures fused at poles* (syncolporate), breviaxial, exine scabrous, thin, pollen triangular in polar view, rarely tetracolporate (quadrangular in polar view)	*Osbornia octadonta*	**(29)**
4. *ectoapertures short* (brevicolporate), free, pollen breviaxial to equiaxial		
5. tricolporate		
6. reticulate-fossulate, costae discontinuous at the equator, endoaperture parallel to the ectoaperture	*Brownlowia argentata* *Brownlowia elata*	**(30)** **(30)**
6. foveolate-fossulate, sometimes verrucate-		

rugulate, costae colpi discontinous at the equator, endoaperture perpendicular to the ectoaperture — *Pelliciera rhizophorae* (31)

6. spinulate, endoaperture with costae pori — *Camptostemon philippensis* (32)

5. tetracolporate-pentacolporate, rarely tricolporate, finely reticulate-scabrous, fastigiate, costae colpi and costae pori present — *Xylocarpus spp.* (33, 34)

3. ***with 3 pseudocolpi***

4. *6-lobed in polar view*, more or less elliptic in meridional view, rugulate-reticulate, infratectum not distinctly columellate, endoaperture perpendicular to the ectoaperture

5. polar axis 11-13 µm — *Conocarpus erectus* (35)

5. polar axis 28-37 µm, dome shaped in polar optical section

6. exine rugulate-reticulate — *Lumnitzera littorea* (35)

6. exine reticulate — *Lumnitzera racemosa* (35)

4. *not 6 lobed in polar view*, exine verrucate-rugulate at the equatorial region, smooth or perforate or verrucate-rugulate at polar region, colpi and pseudocolpi sometimes poorly or not differentiated; abnormal pollen 4 or 6 aperturate — *Sonneratia spp.* (36-42)

5. colpi and pseudocolpi more or less readily distinguishable

6. exine smooth to perforate at polar region, verrucate-rugulate at the equatorial region — *Sonneratia alba* (36-38); *Sonneratia griffithii* (39)

6. exine ± uniformly verrucate-rugulate — *Sonneratia ovata* (40)

5. colpi and pseudocolpi rarely distinguishable, aperture almost reduced to pores (triporate)

6. exine smooth-peforate at polar region, verrucate-rugulate at equatorial region — *Sonneratia caseolaris* (41)

6. exine uniformly rugulate — *Sonneratia apetala* (42)

2. **triporate**: see just above, § 4. — *Sonneratia spp.* (36-42)

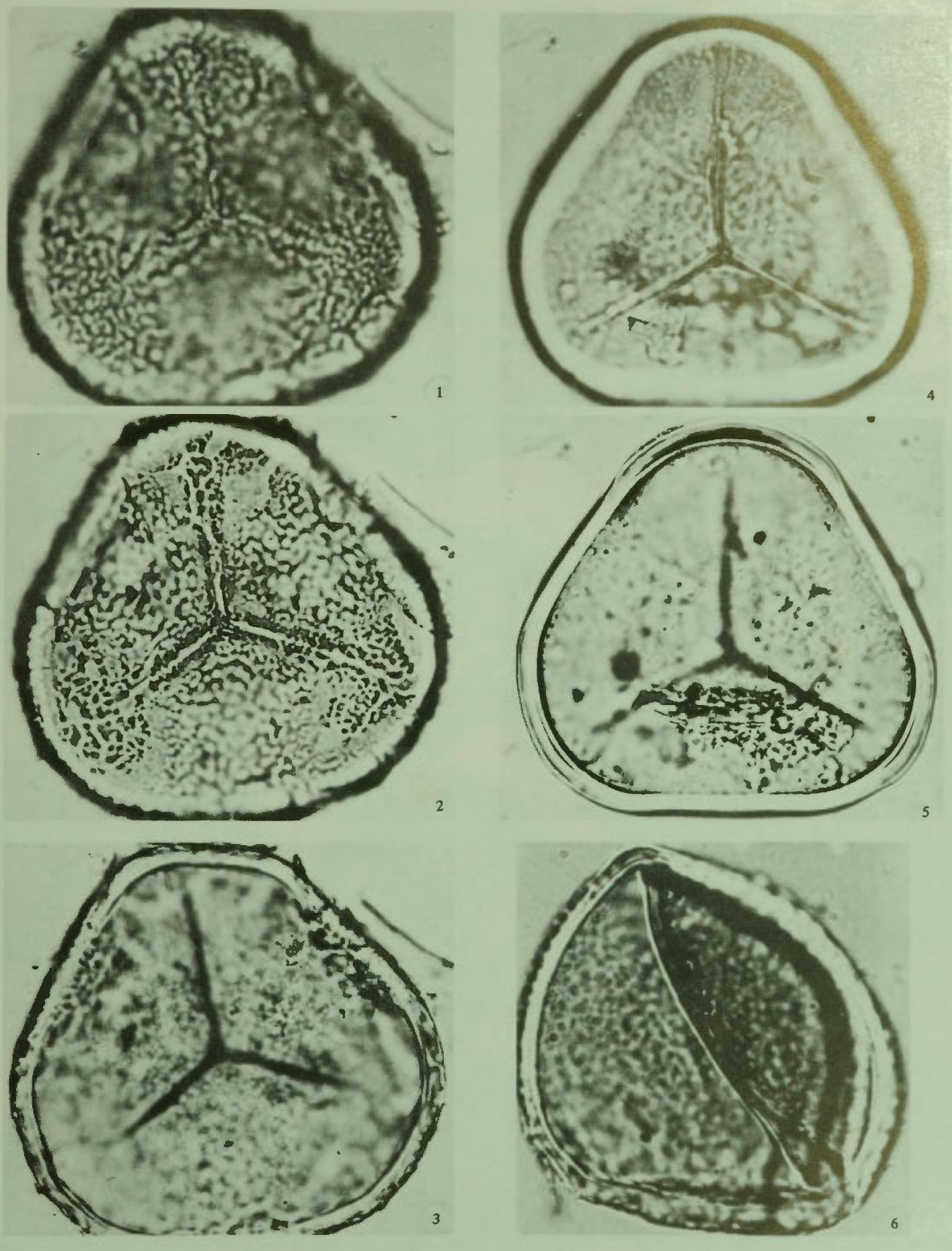


PLATE 1. Pteridaceae: *Acrostichum aureum* 1–6, x 1000, acetolysed.

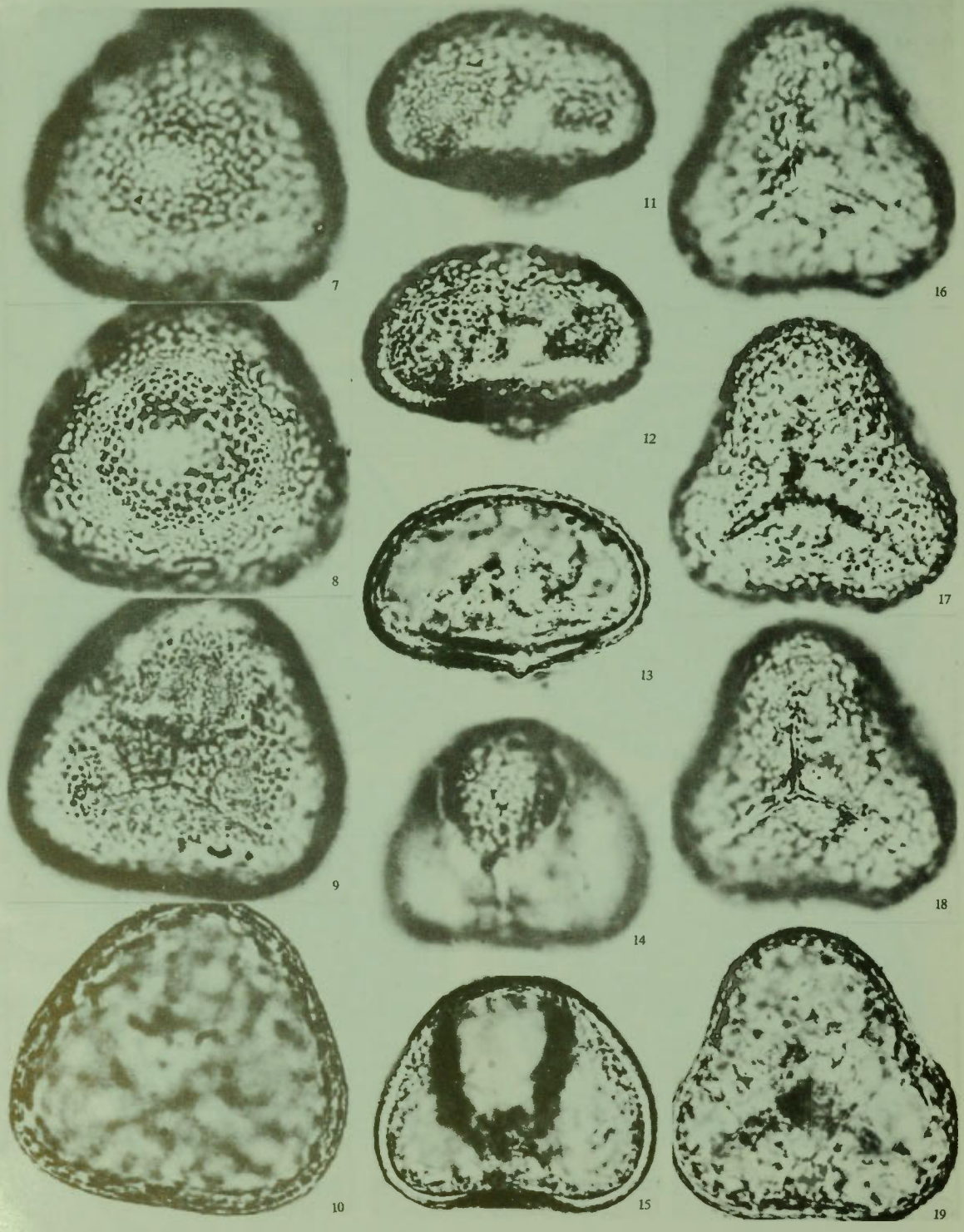


PLATE 2. Pteridaceae: *Acrostichum aureum* 7–19, x 1000, Wodehouse technique.

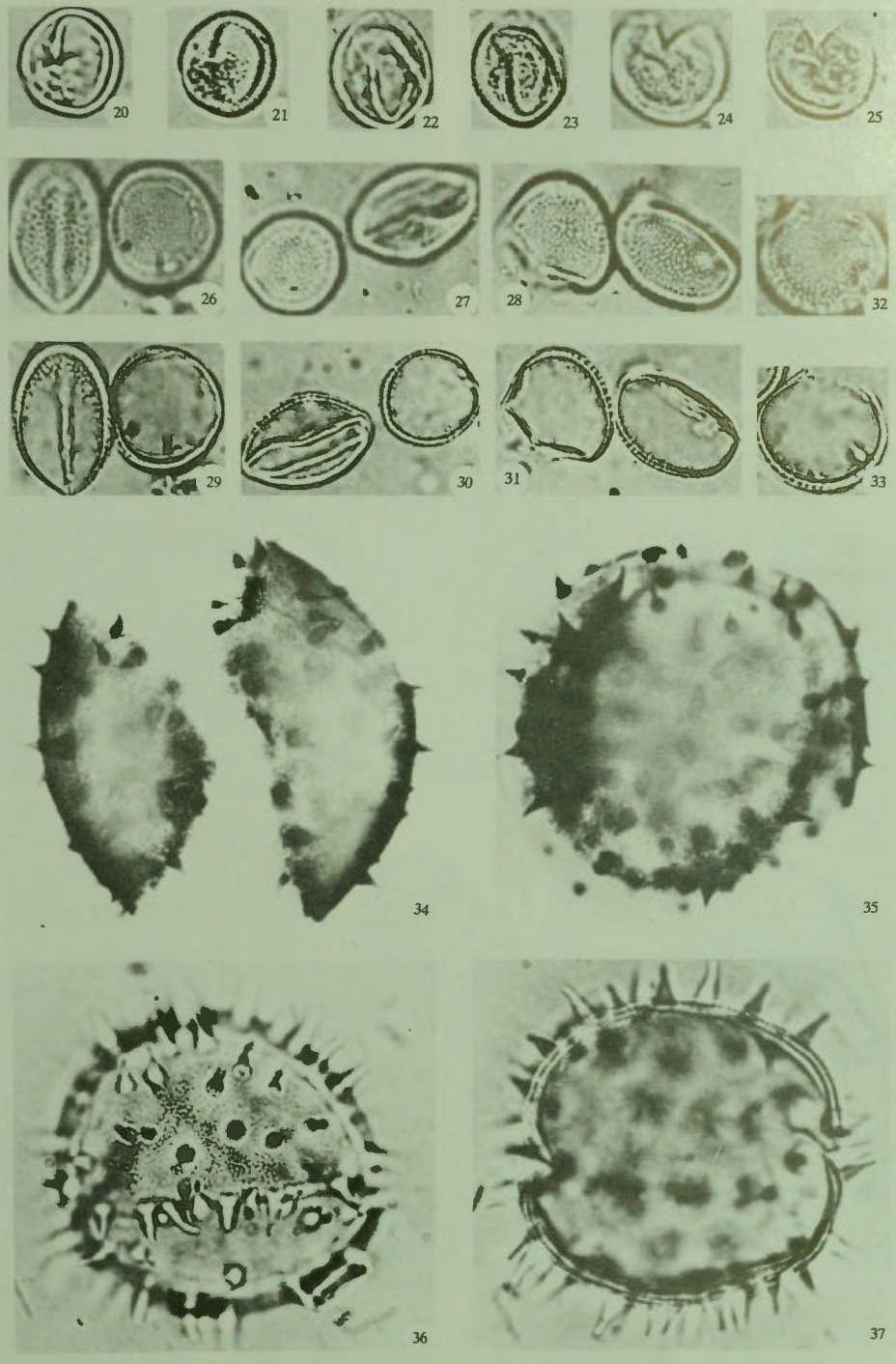
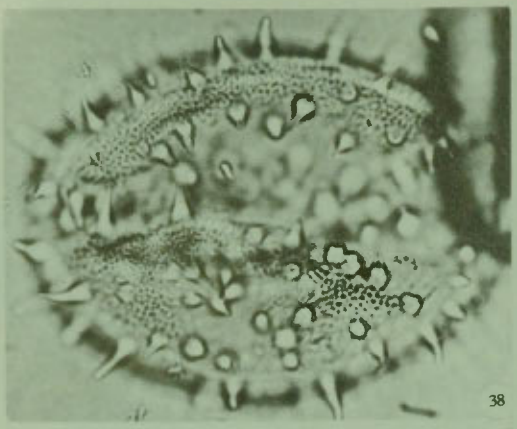
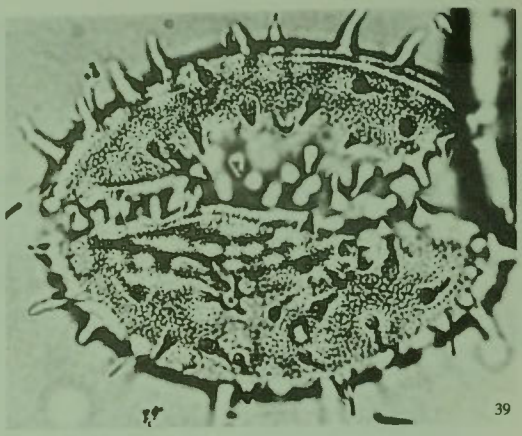


PLATE 3. Arecaceae: *Phoenix paludosa* 20–25, x 1000, Wodehouse technique; 26–33, x 1000, acetolysed. *Nypa fruticans* 34–35, x 1000, Wodehouse technique; 36–37, x 1000, acetolysed.





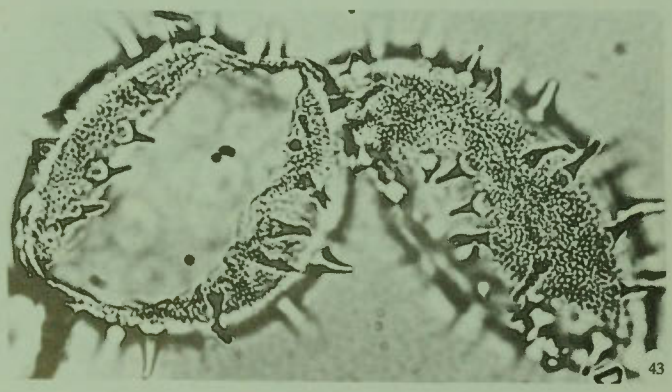


PLATE 4. Arecaceae: *Nypa fruticans* 38–43, x 1000, acetolysed; 42: abnormal verrucate spinessly pollen.

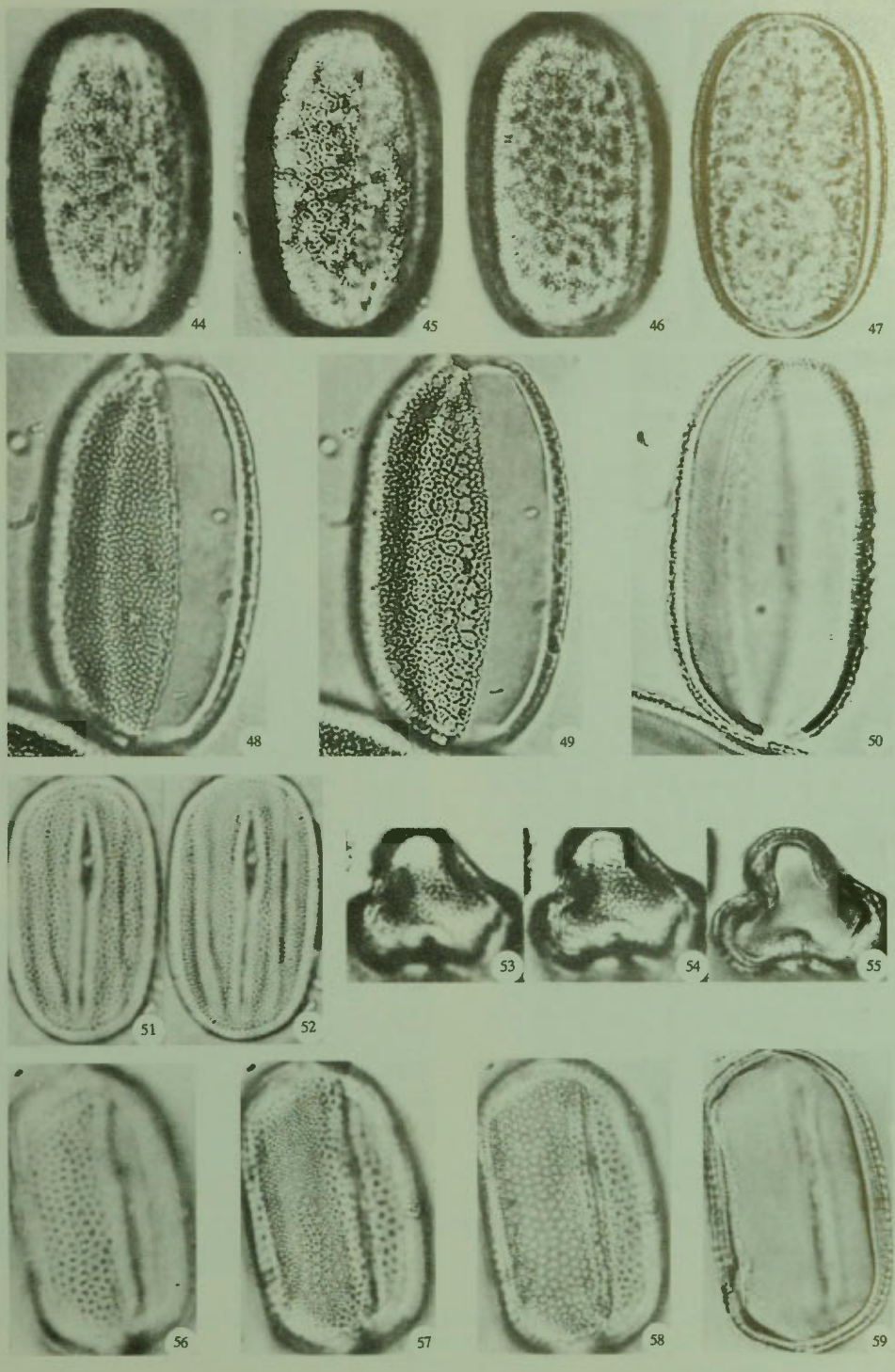
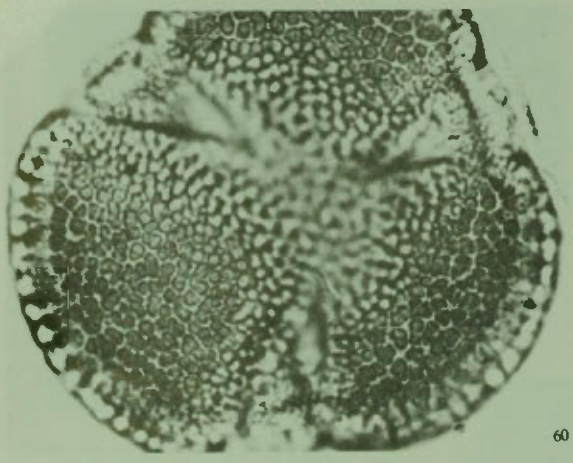
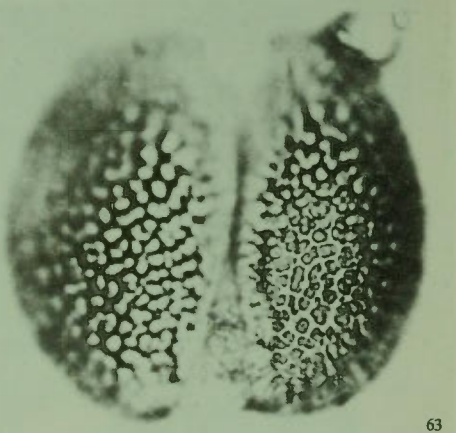
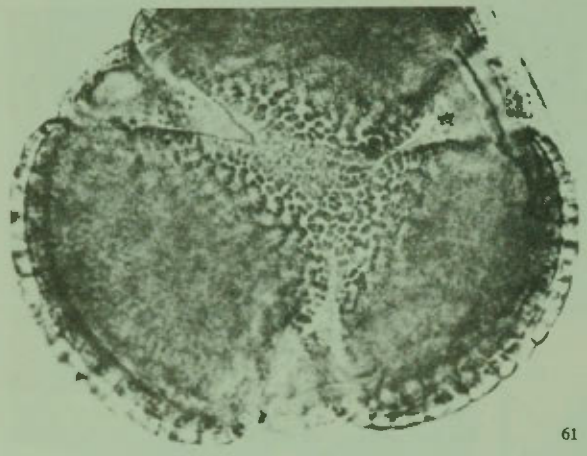


PLATE 5. Acanthaceae: *Acanthus ilicifolius* 44–47, x 1000, Wodehouse technique (apertural membrane with granules); 48–50, x 1000, acetolysed. *Acanthus ebracteatus* 51–52, x 750, acetolysed; 53–59, x 1000, acetolysed.







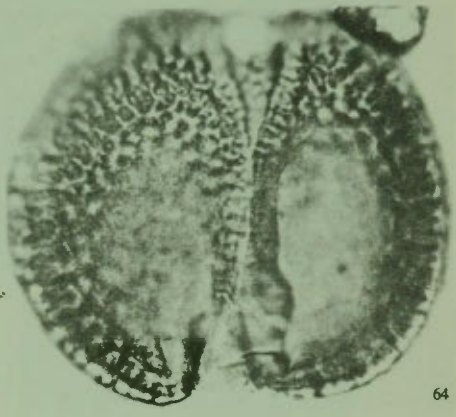
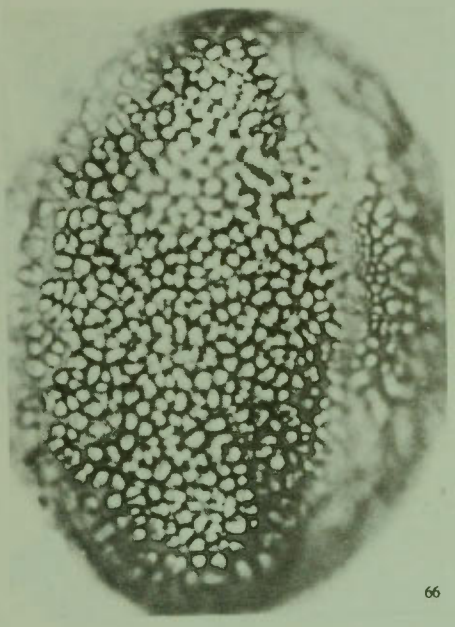
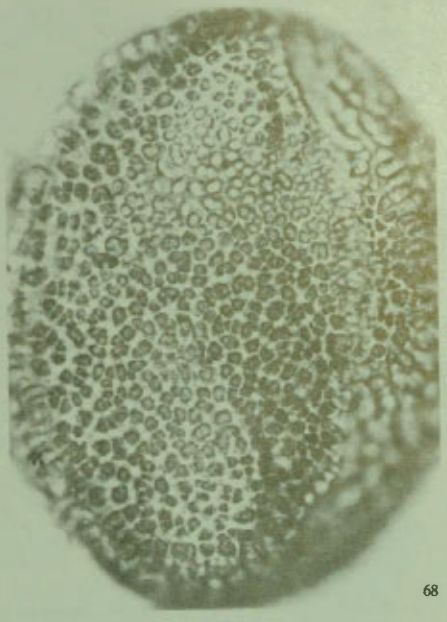
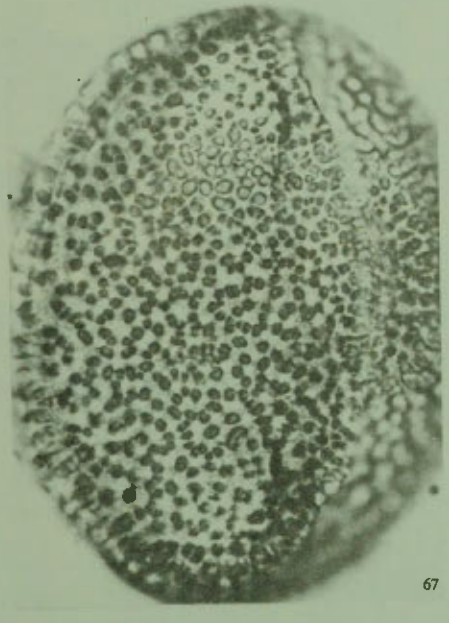


PLATE 6. Plumbaginaceae: *Aegialitis annulata* 60–65, x 1000, acetolysed; 63–65: abnormal grain, dicolpate.







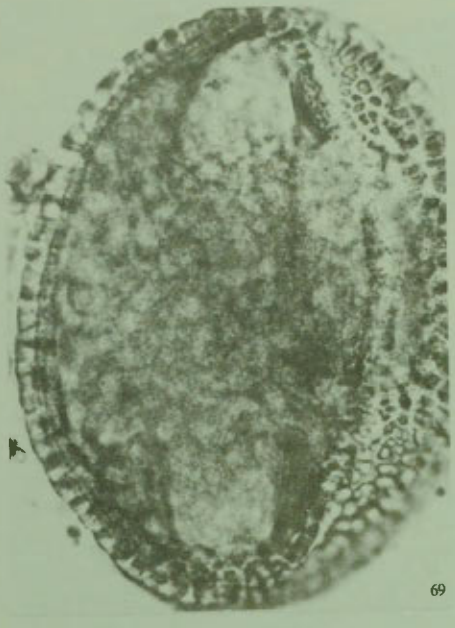
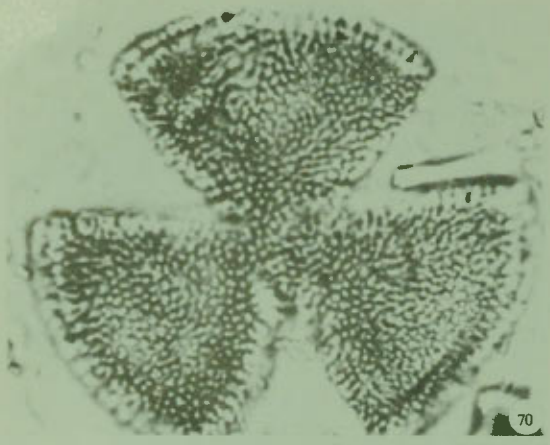
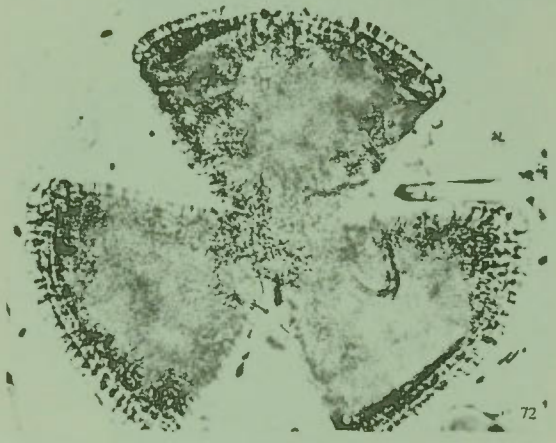
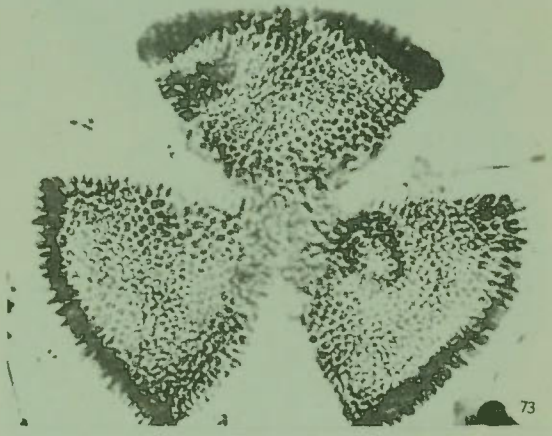
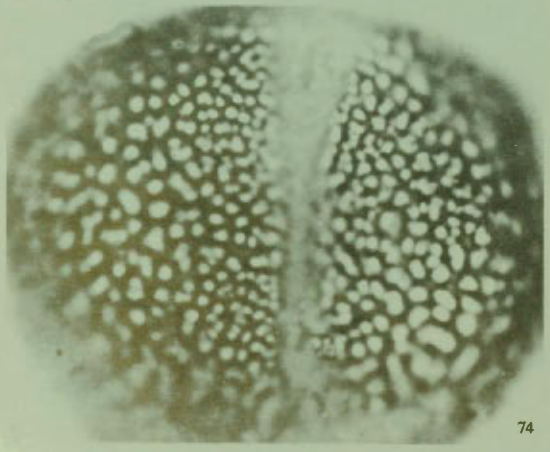


PLATE 7. Plumbaginaceae: *Aegialitis annulata* 66–69, x 1000, acetolysed.









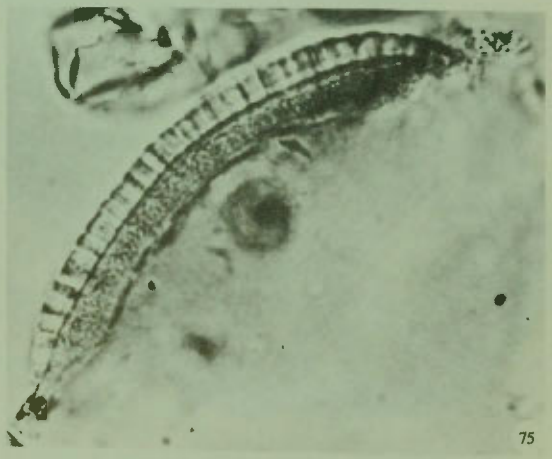


PLATE 8. Plumbaginaceae: *Aegialitis rotundifolia* 70–75, x 1000, acetolysed.

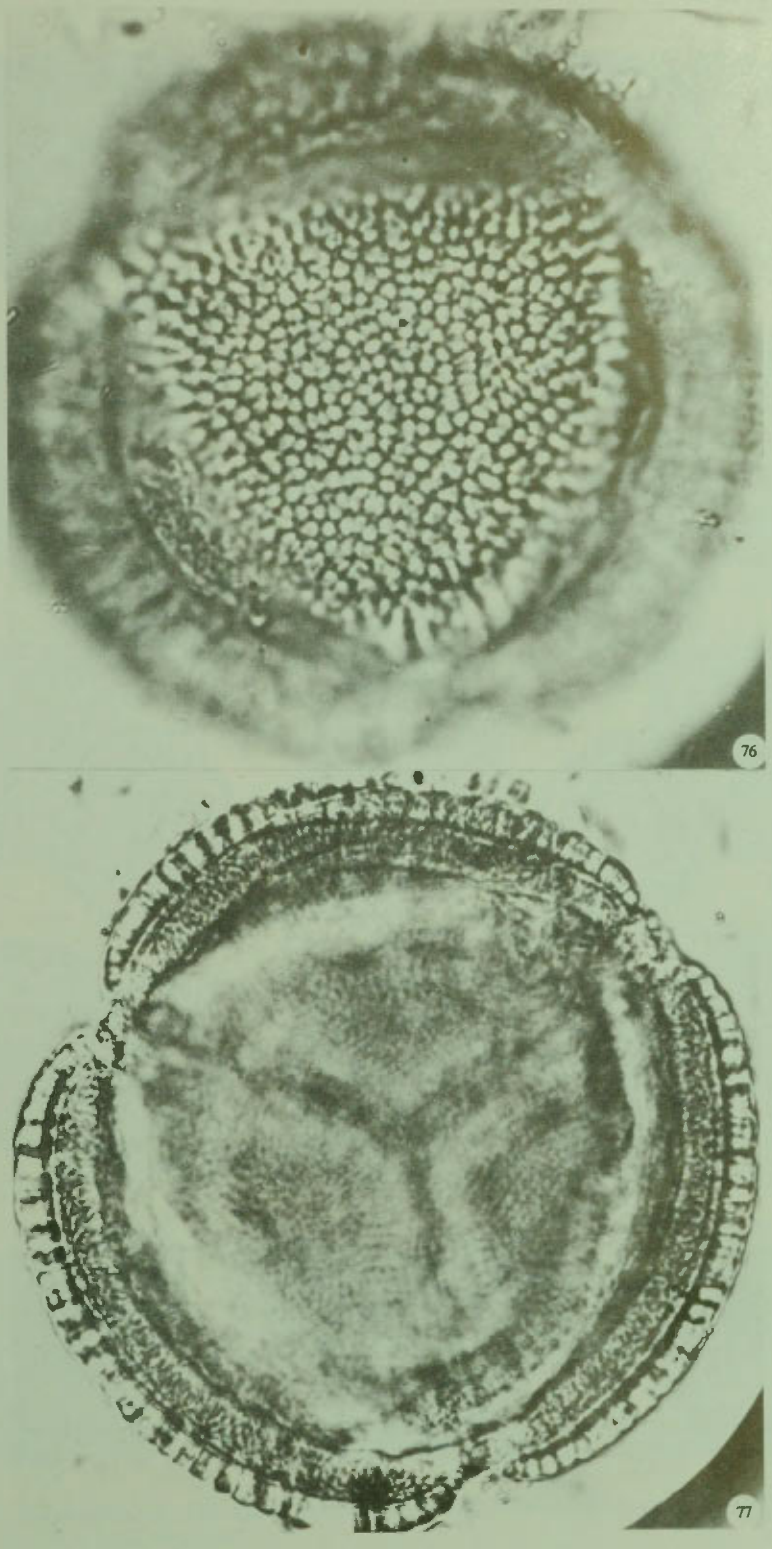


PLATE 9. Plumbaginaceae: *Aegialitis rotundifolia* 76–77, x 1000, acetolysed, abnormal (dyad?) pollen.

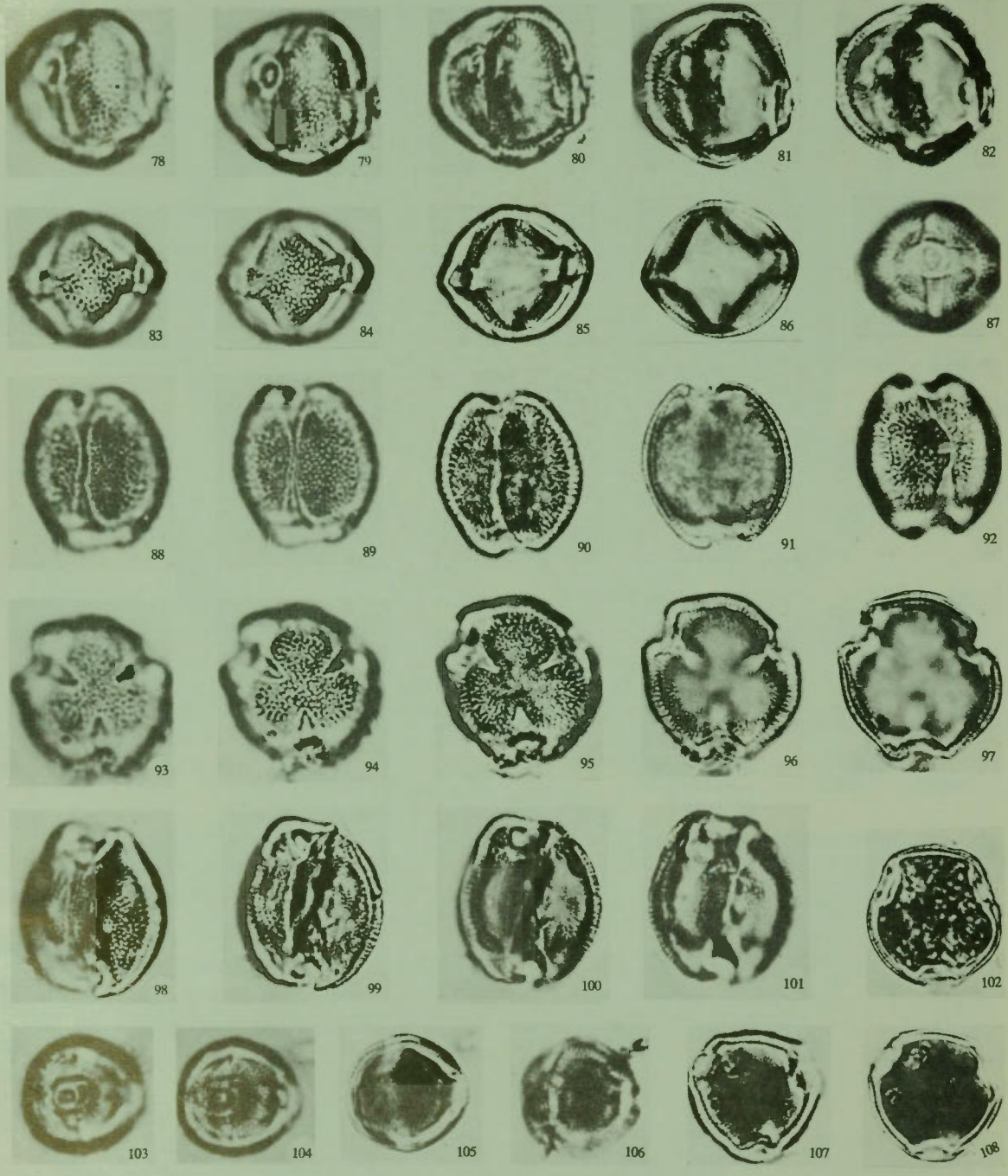
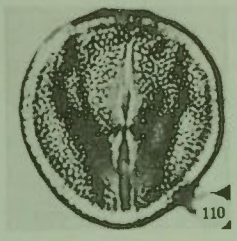
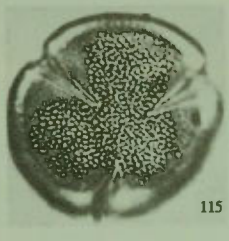
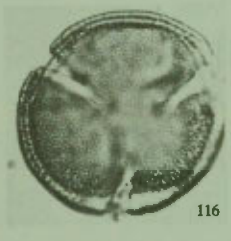
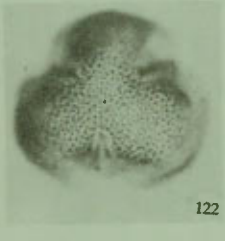


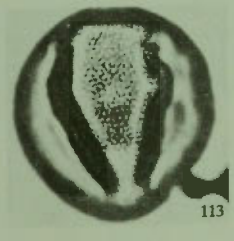
PLATE 10. Rubiaceae: *Scyphiphora hydrophyllacea* 78–101, x 1000, acetolysed; 102–108, x 1000, Wodehouse technique; 88–92 and 98–101, abnormal grains, disyncolporate.











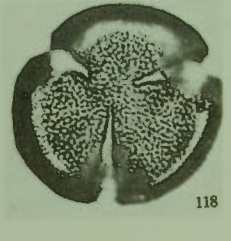


PLATE 11. Euphorbiaceae: *Excoecaria agallocha* 109–120, x 1000, acetolysed; 121, x 1000, Wodehouse technique; 122–123, x 1000, acetolysed.

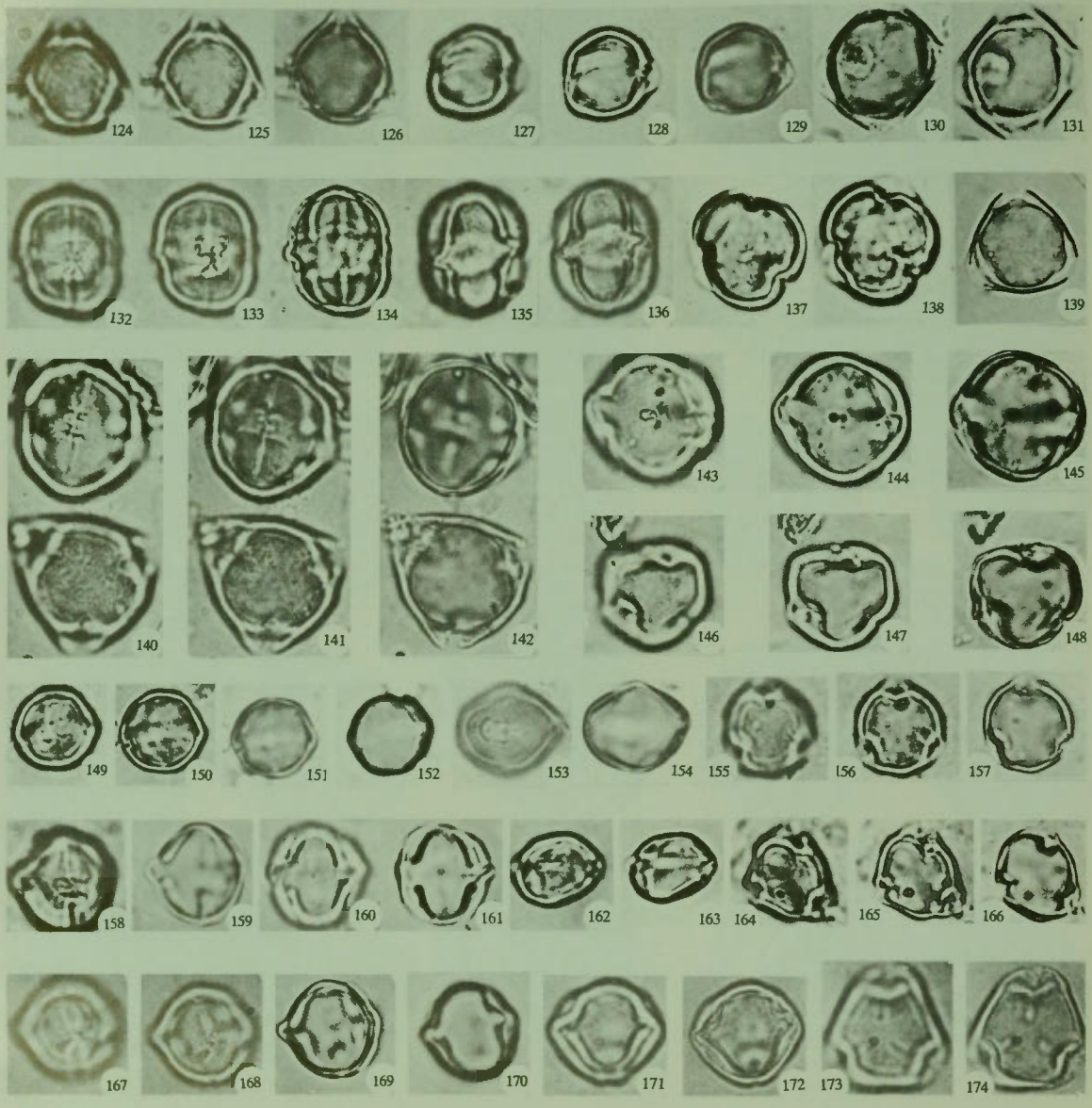


PLATE 12. Rhizophoraceae: *Bruguiera cylindrica* 124–131, x 1000, acetolysed; 130–131: abnormal grain, tetracolporate. *Bruguiera exaristata* 132–138, x 1000, acetolysed; 139, x 1000, Wodehouse technique. *Bruguiera gymnorhiza* 140–148, x 1000, acetolysed. *Bruguiera hainesii* 149–157, x 1000, acetolysed. *Bruguiera parviflora* 158–166, x 1000, acetolysed. *Bruguiera sexangula* 167–174, x 1000, acetolysed.

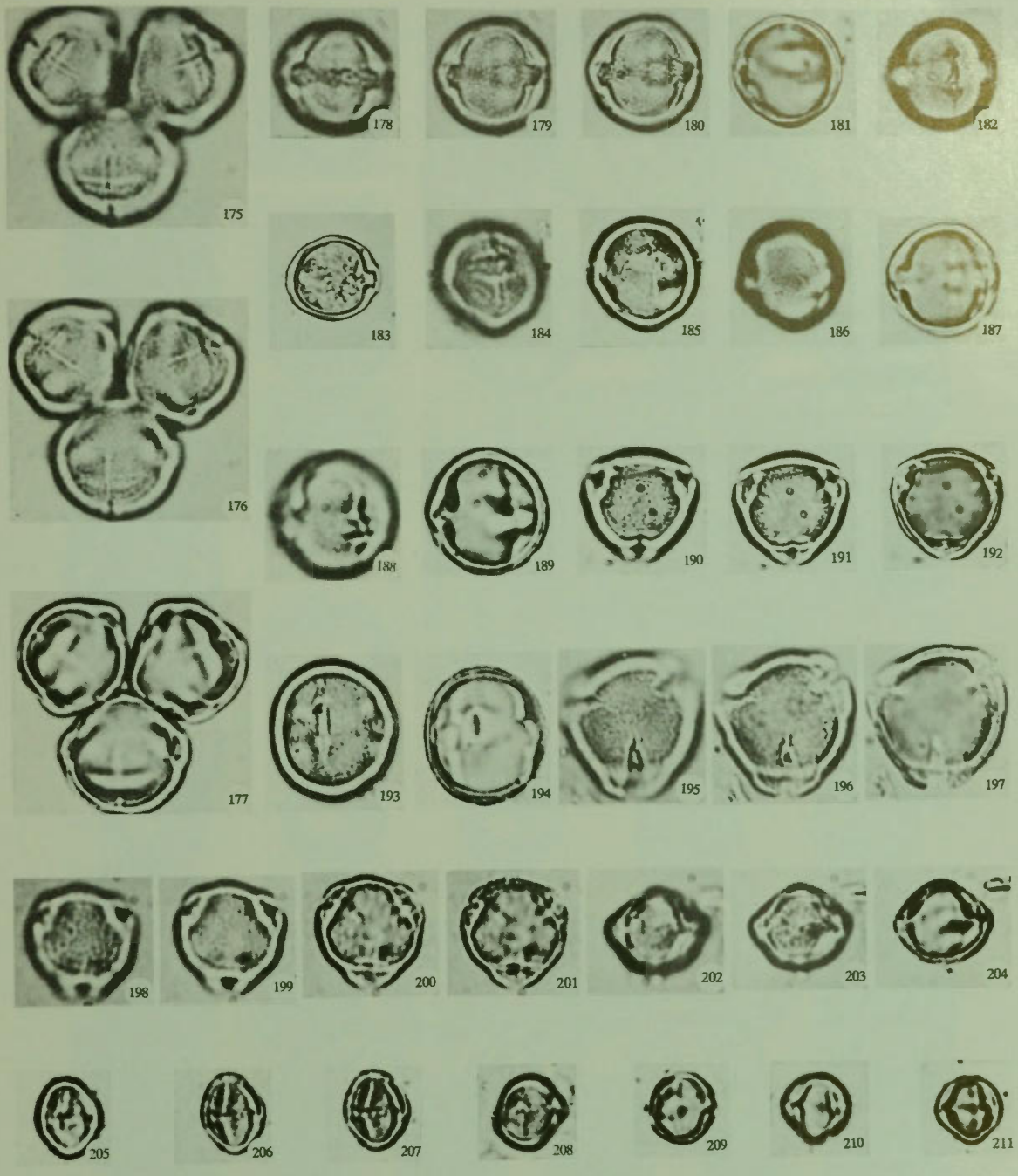


PLATE 13. Rhizophoraceae: *Ceriops decandra* 175–182 and 184–197, x 1000, acetolysed; 183, x 1000, Wodehouse technique. *Ceriops tagal* 198–211, x 1000, acetolysed.

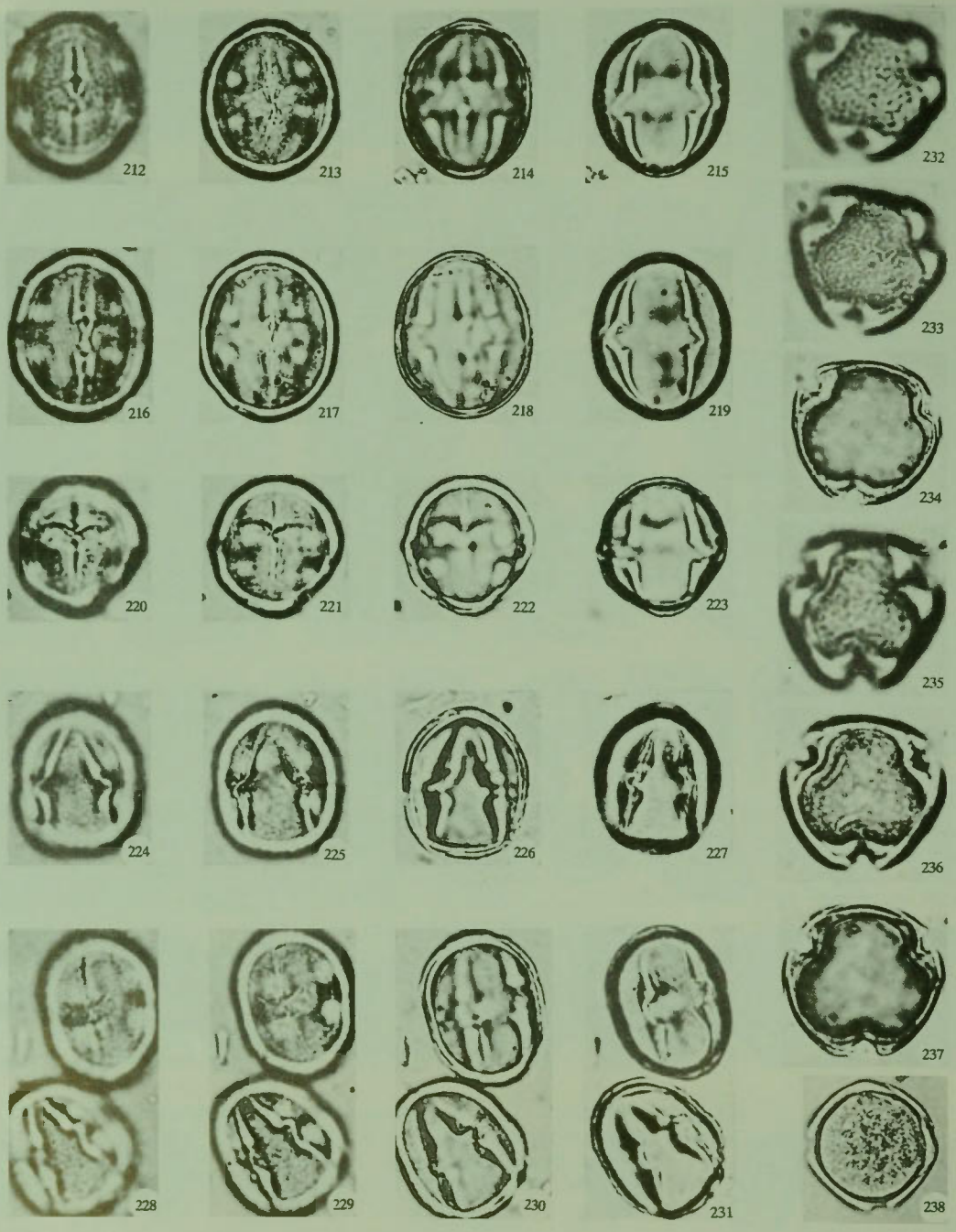


PLATE 14. Rhizophoraceae: *Kandelia candel* 212–237, x 1000, acetolysed; 238, x 1000, Wodehouse technique, abnormal grain, tetracolporate.

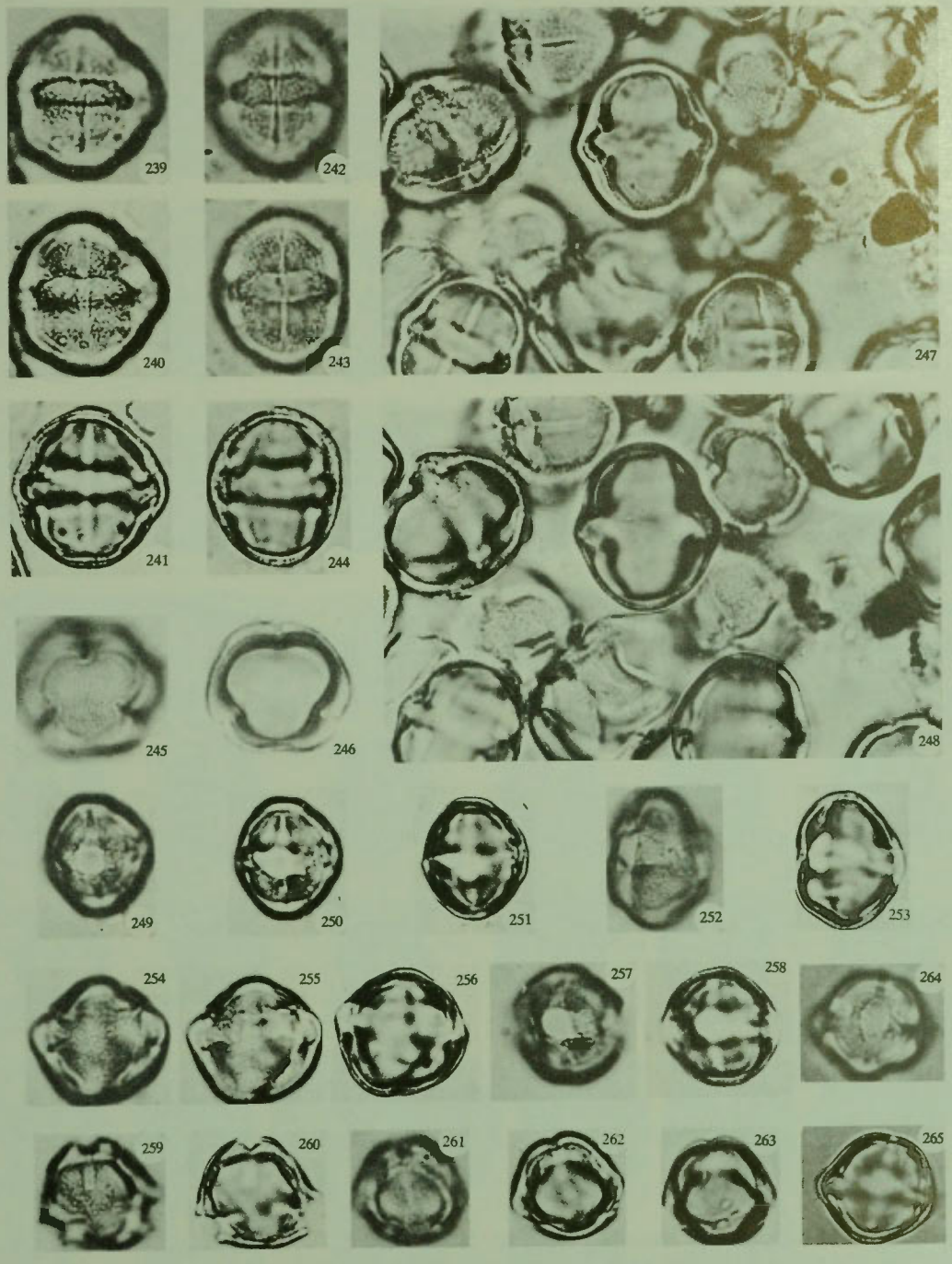


PLATE 15. Rhizophoraceae: *Rhizophora apiculata* 239–248, x 1000, acetolysed; *Rhizophora harrisonii* 249–263, x 1000, acetolysed; 264–265, x 1000 Wodehouse technique.

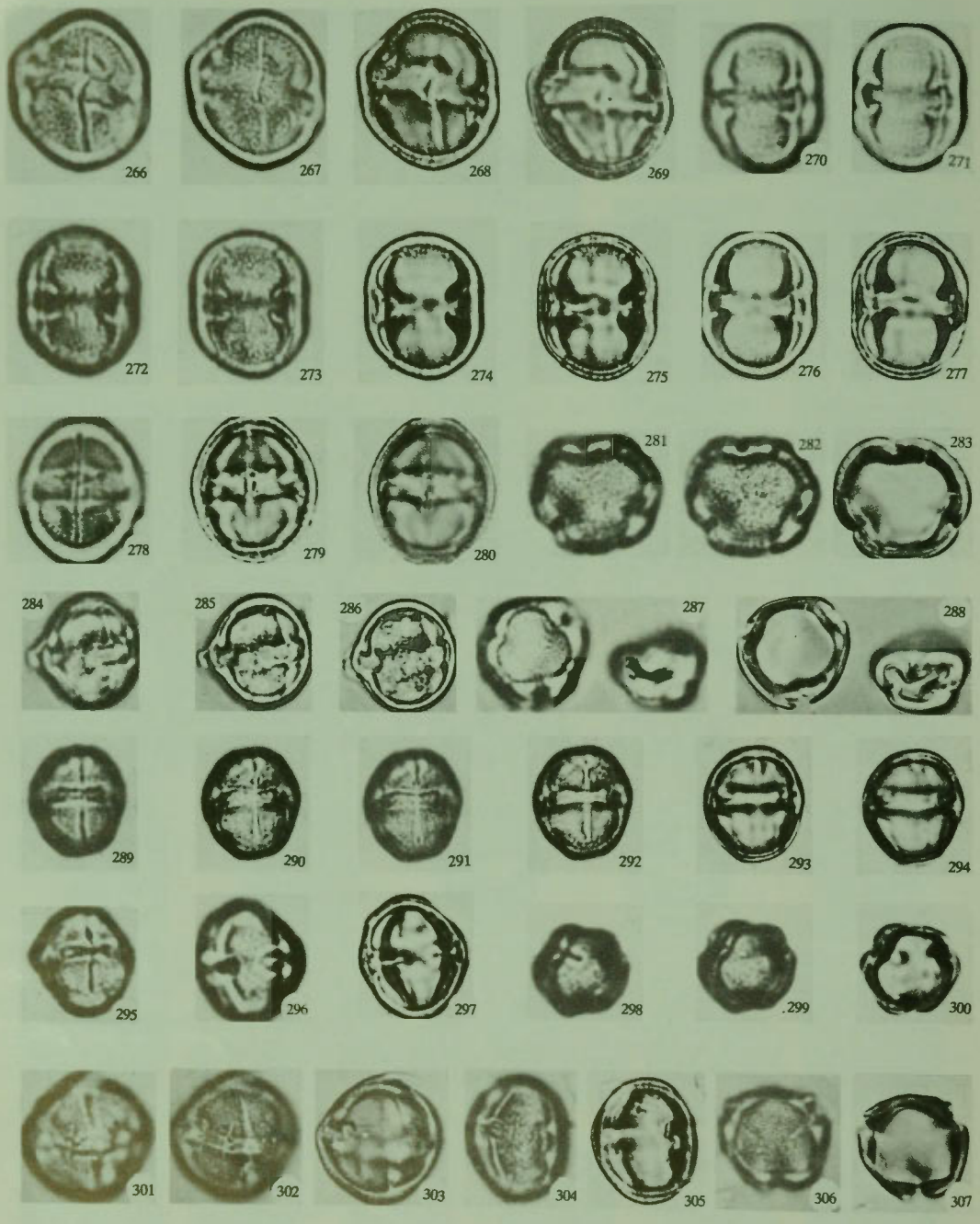


PLATE 16. Rhizophoraceae: *Rhizophora lamarckii* 266–283 and 289–300, x 1000, acetolysed; 284–288, x 1000 Wodehouse technique; *Rhizophora mangle* 301–307, x 1000, acetolysed.

PLATE 17. Rhizophoraceae: *Rhizophora mucronata* 308–312 and 314–327, x 1000, acetolysed; 326–327, abnormal grain, dicolporate; 313, x 1000, Wodehouse technique, abnormal grain, tetracolporate. *Rhizophora racemosa* 328–339, x 1000, acetolysed; 337–338, abnormal grain, dicolporate. *Rhizophora stylosa* 340–351, x 1000, acetolysed.

PLATE 18. Combretaceae: *Laguncularia racemosa* 352–357 and 358–363, x 1000, acetolysed; 364–365, x 1000, Wodehouse technique. **Myrsinaceae**: *Aegiceras corniculatum* 366–384, x 1000, acetolysed; 377–378 and 382–384, abnormal grain, tetracolporate. *Aegiceras floridum* 385–390, x 1000, acetolysed; 391–393, x 1000, abnormal grain, tetracolporate.

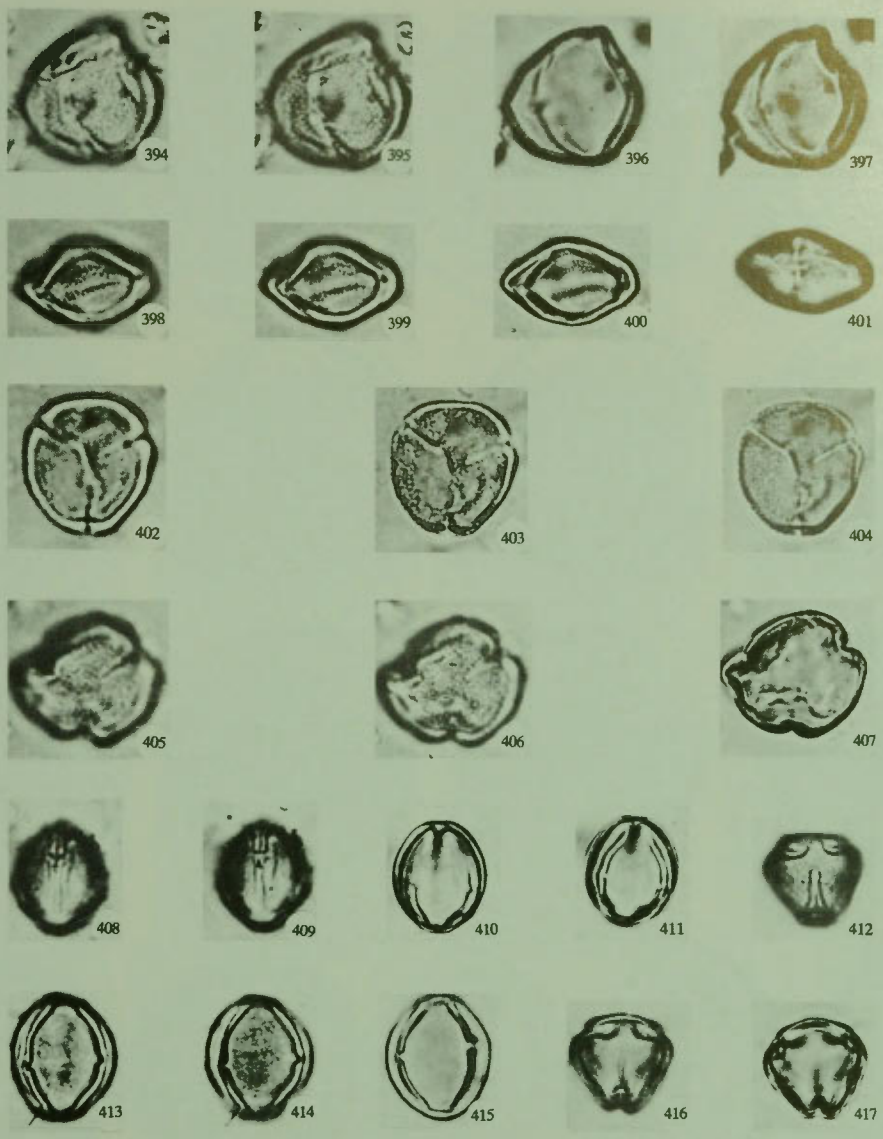


PLATE 19. Sterculiaceae: *Heritiera fomes* 394–407, x 1000, acetolysed. *Heritiera littoralis* 408–417, x 1000, acetolysed.

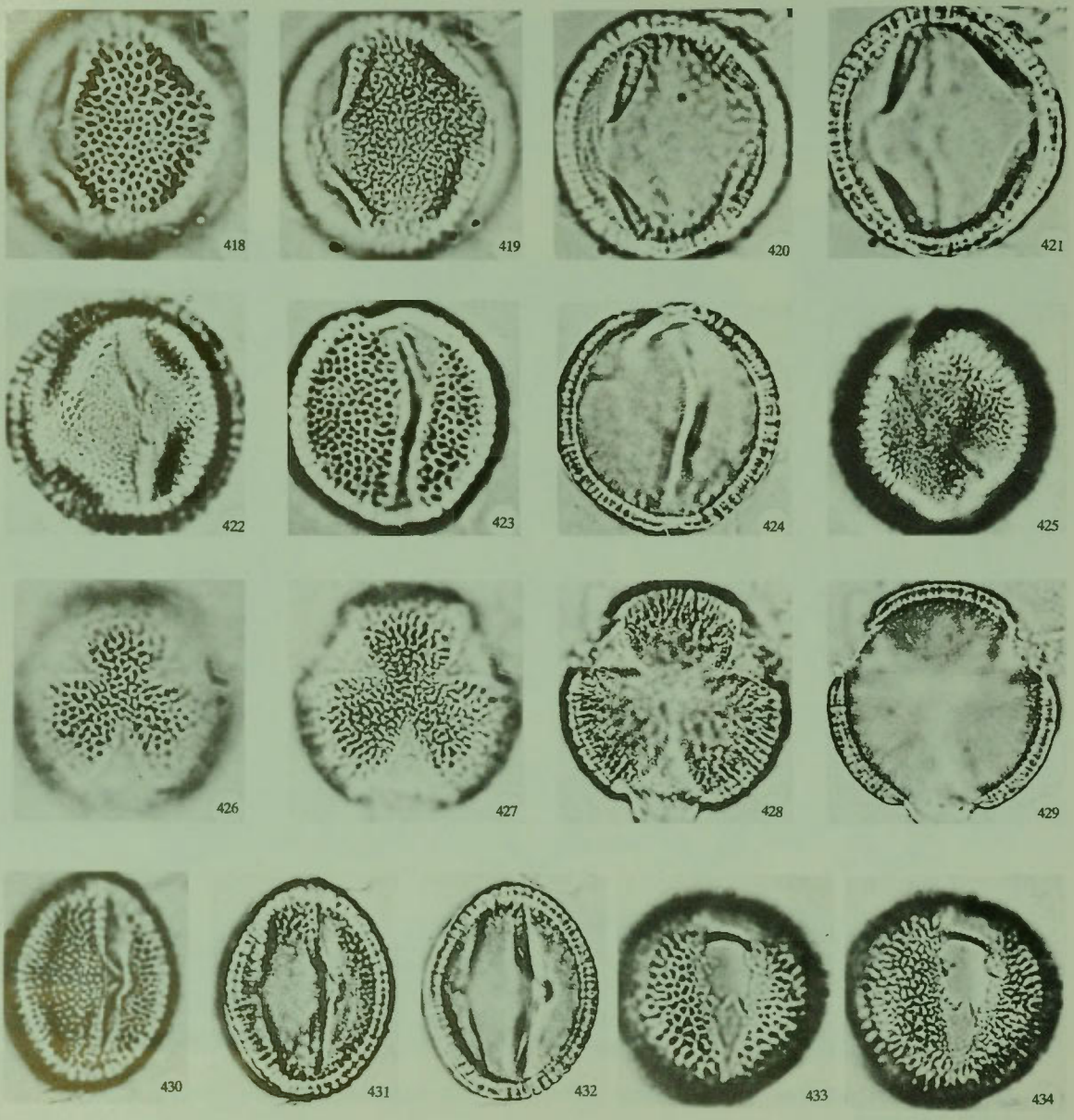


PLATE 20. Avicenniaceae: *Avicennia africana* 418–434, x 1000, acetolysed; 423–425, abnormal grain, dicolporate.

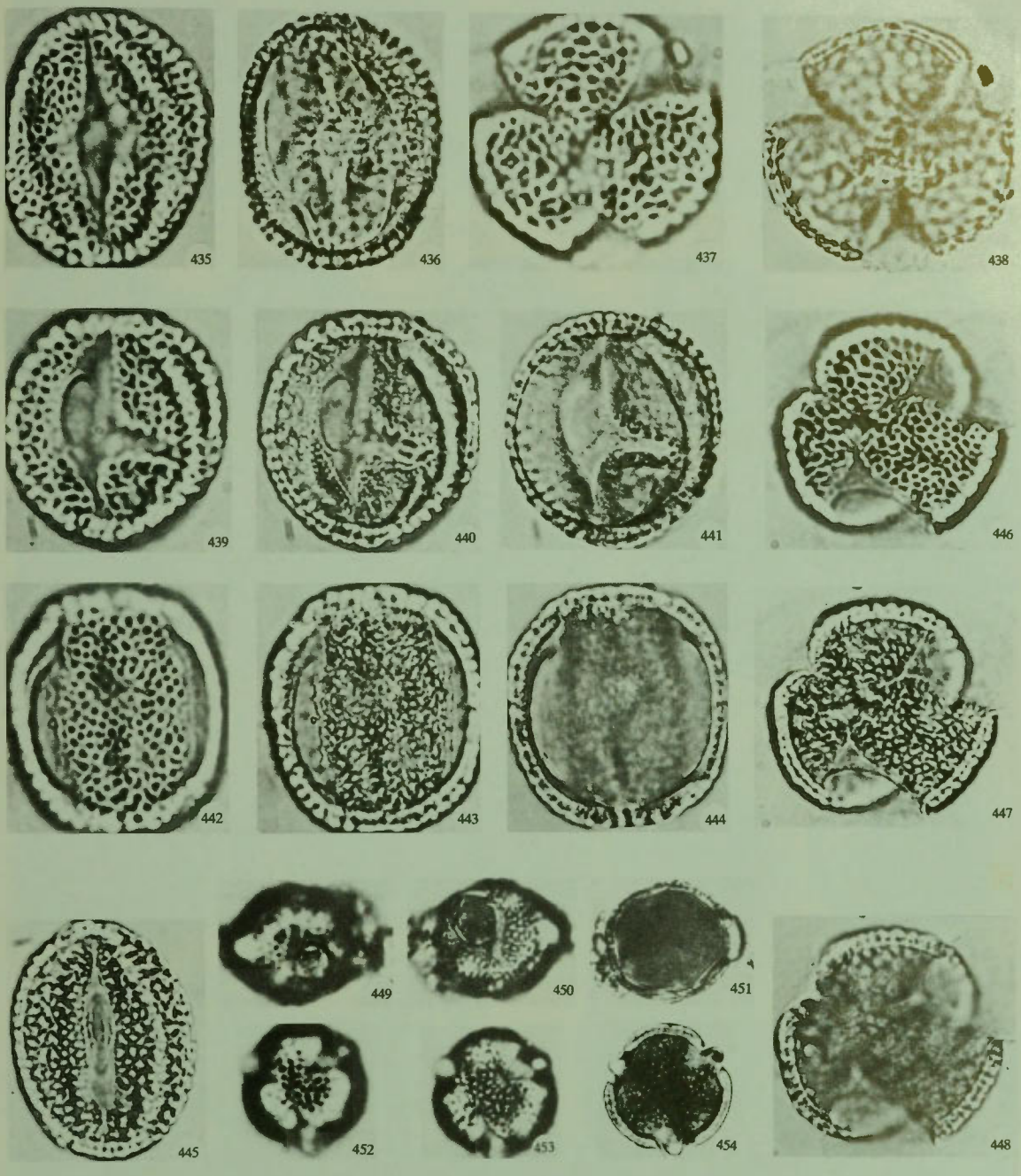


PLATE 21. Avicenniaceae: *Avicennia alba* 435–448, x 1000, acetolysed; 449–454, x 1000, Wodehouse technique.

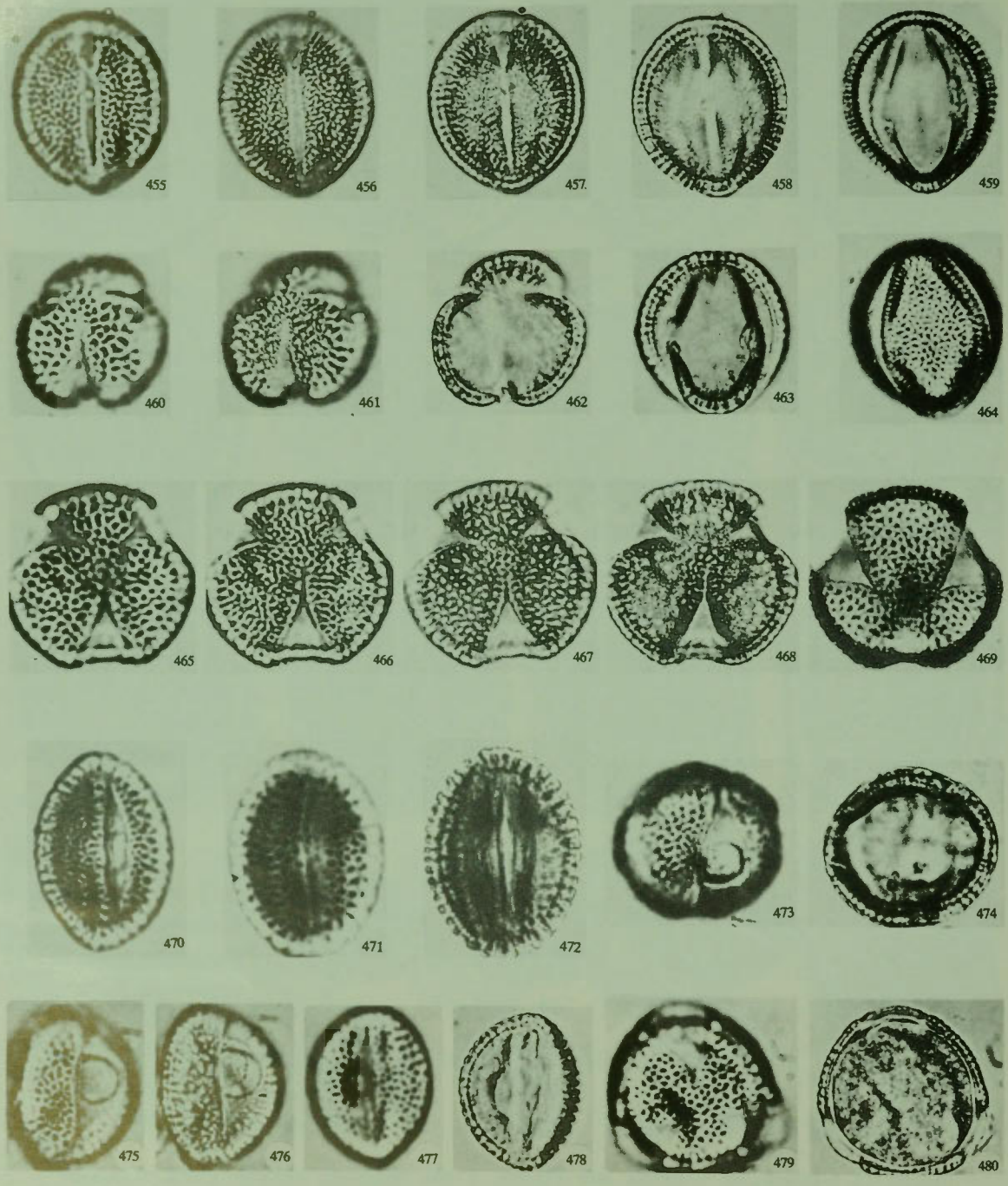


PLATE 22. Avicenniaceae: *Avicennia bicolor* 455–464, x 1000, acetolysed. *Avicennia eucalyptifolia* 465–474, x 1000, acetolysed; 475–480, x 1000, Wodehouse technique.

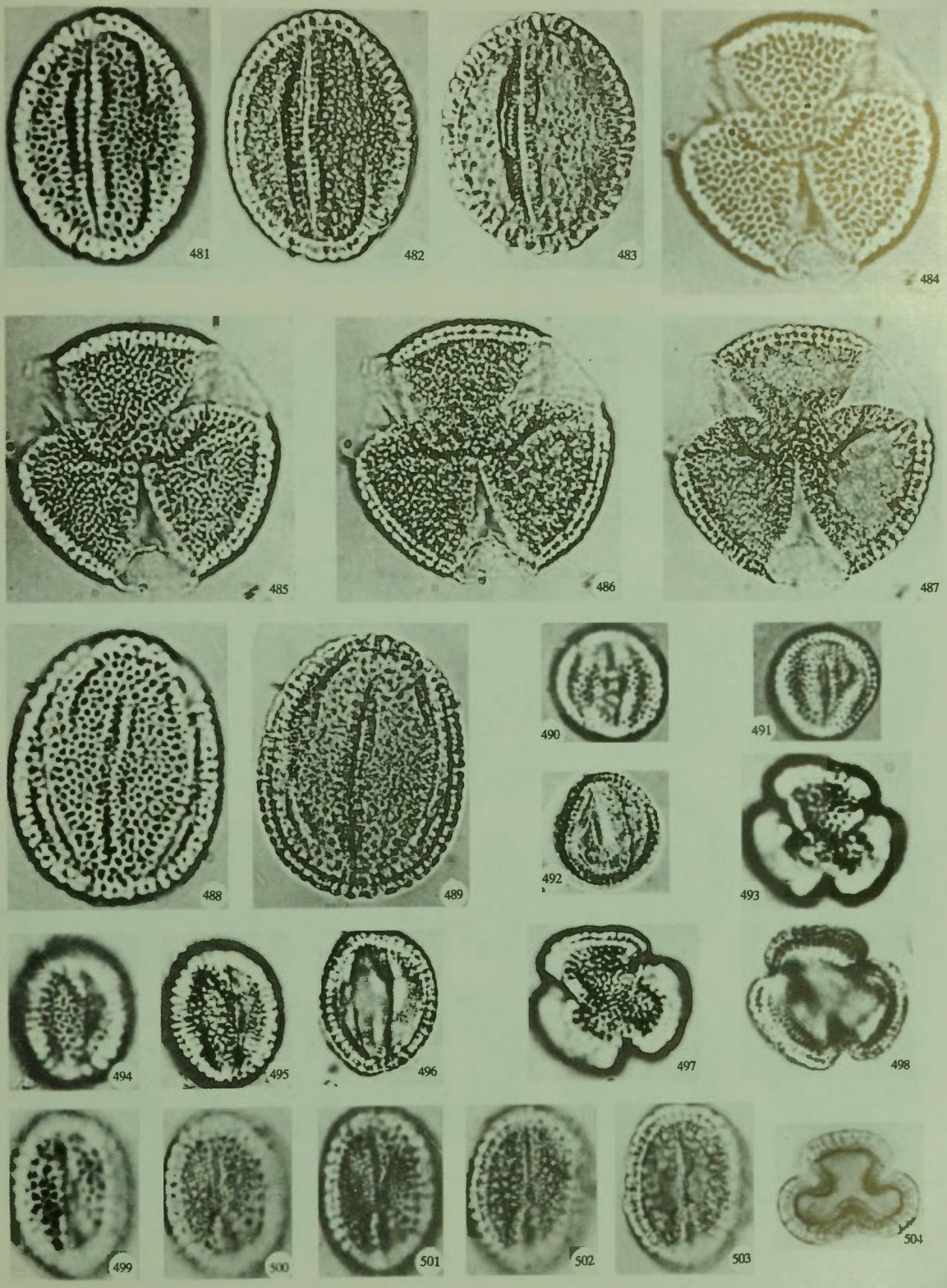


PLATE 23. Avicenniaceae: *Avicennia germinans* 481–489, x 1000, acetolysed. *Avicennia lanata* 490–492, x 1000, Wodehouse technique; 493–504, x 1000, acetolysed.

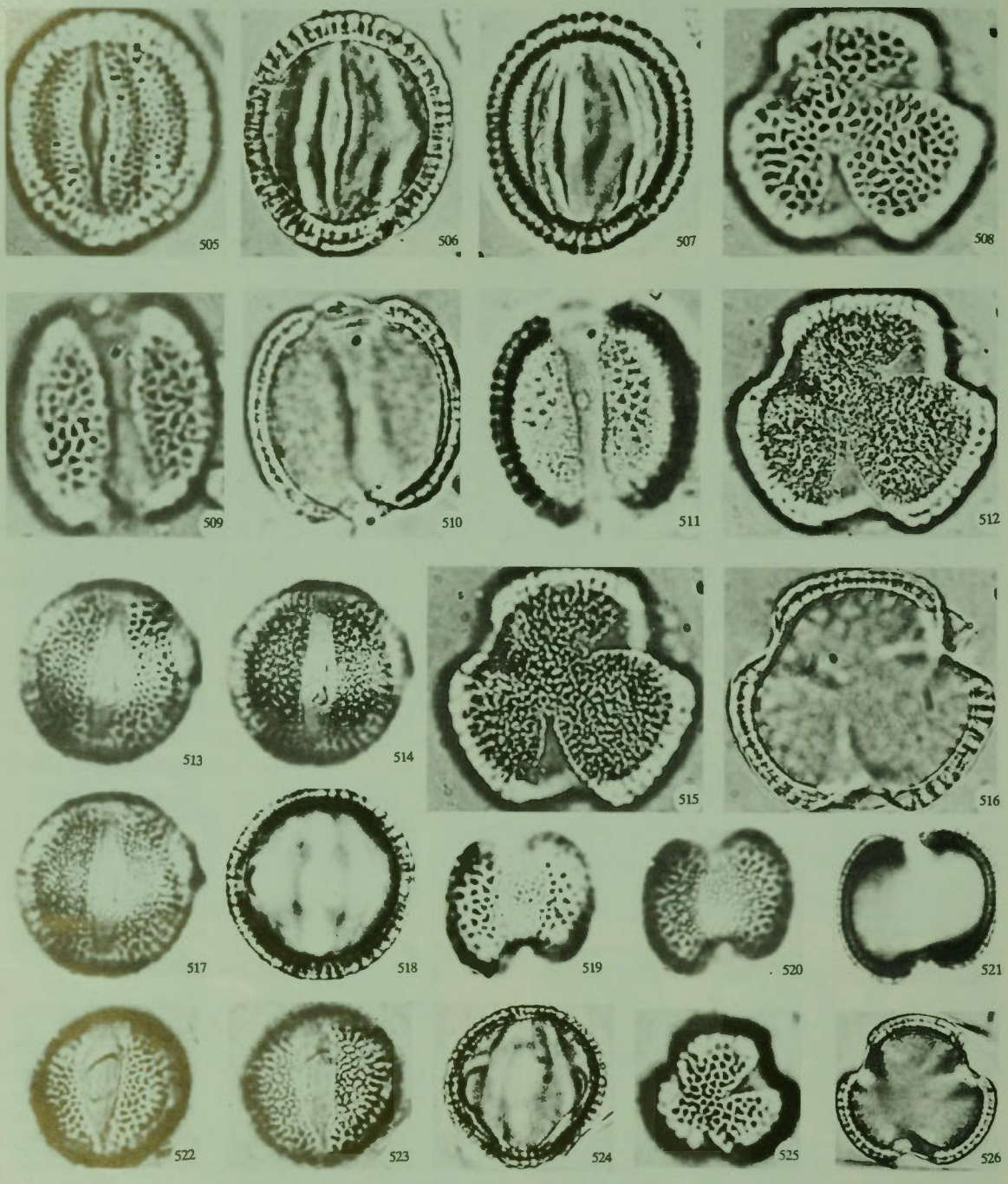


PLATE 24. Avicenniaceae: *Avicennia marina* var. *marina* 505–526, x 1000, acetolysed; 509–511 and 519–521, abnormal grains, dicolporate.

PLATE 25. Avicenniaceae: *Avicennia marina* var. *acutissima* 527–532, x 1000, acetolysed; 533, x 1000, Wodehouse technique. *Avicennia marina* var. *resinifera* 534–543, x 1000, acetolysed; 544–546, x 1000, Wodehouse technique.

PLATE 26. Avicenniaceae: *Avicennia marina* var. *rumphiana*, 547–555, x 1000, acetolysed. *Avicennia officinalis* 556–565, x 1000, acetolysed; 556–558, abnormal grain, dicolporate; 566–568, x 1000, Wodehouse technique.

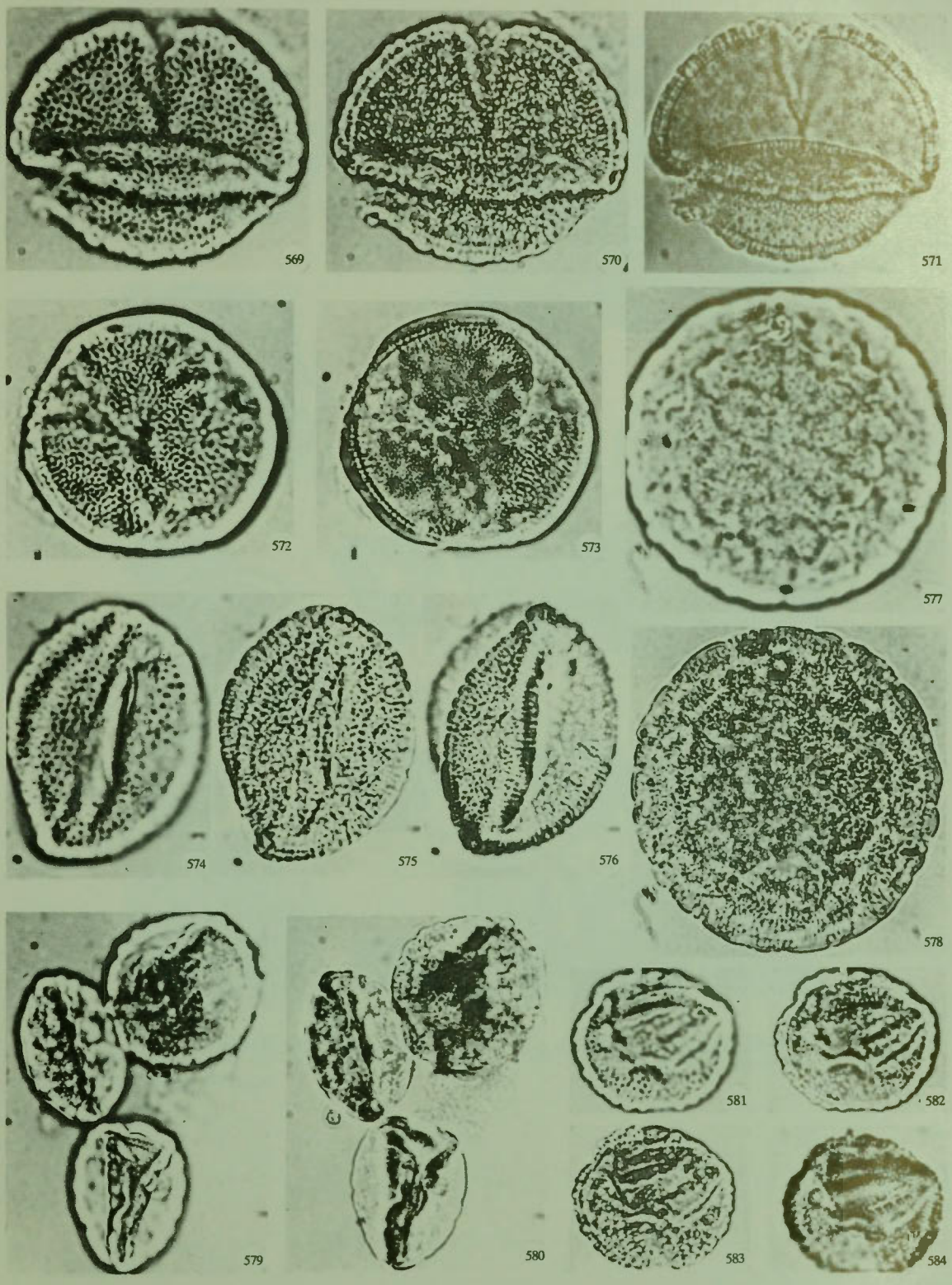


PLATE 27. Avicenniaceae: *Avicennia schaueriana* 569–578, x 1000, acetolysed; 577–578: abnormal grain, inaperturate; 579–580, x 1000, 3 young pollens, Wodehouse technique; 581–584, x 1000, abnormal dyad with 6 periapertures, Wodehouse technique.

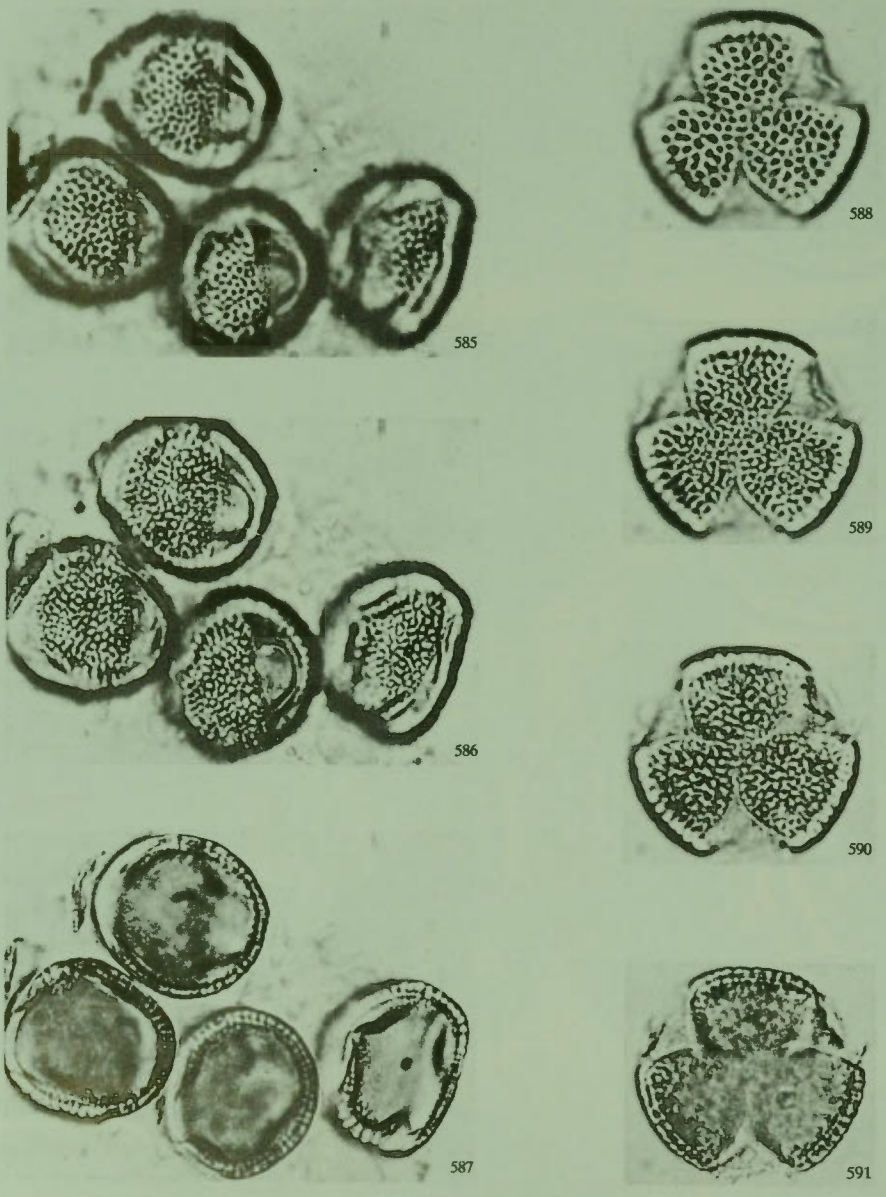


PLATE 28. Avicenniaceae: *Avicennia tonduzii* 585–591, x 1000, acetolysed.

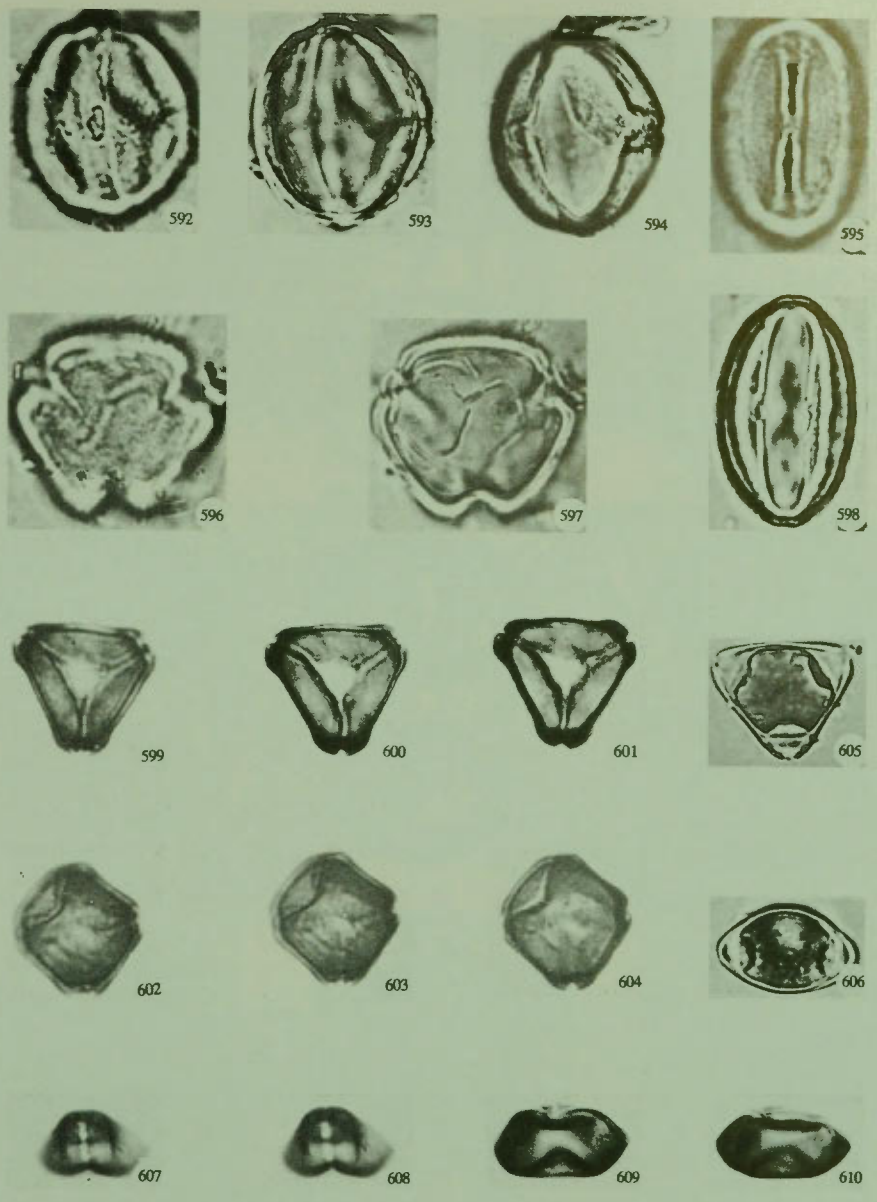


PLATE 29. Caesalpiniaceae: *Cynometra ramiflora* 592–598, x 1000, acetolysed. **Myrtaceae**: *Osbornia octodonta* 599–604 and 607–610, x 1000, acetolysed; 602–604: abnormal grain, tetracolporate; 605–606, x 1000, Wodehouse technique.

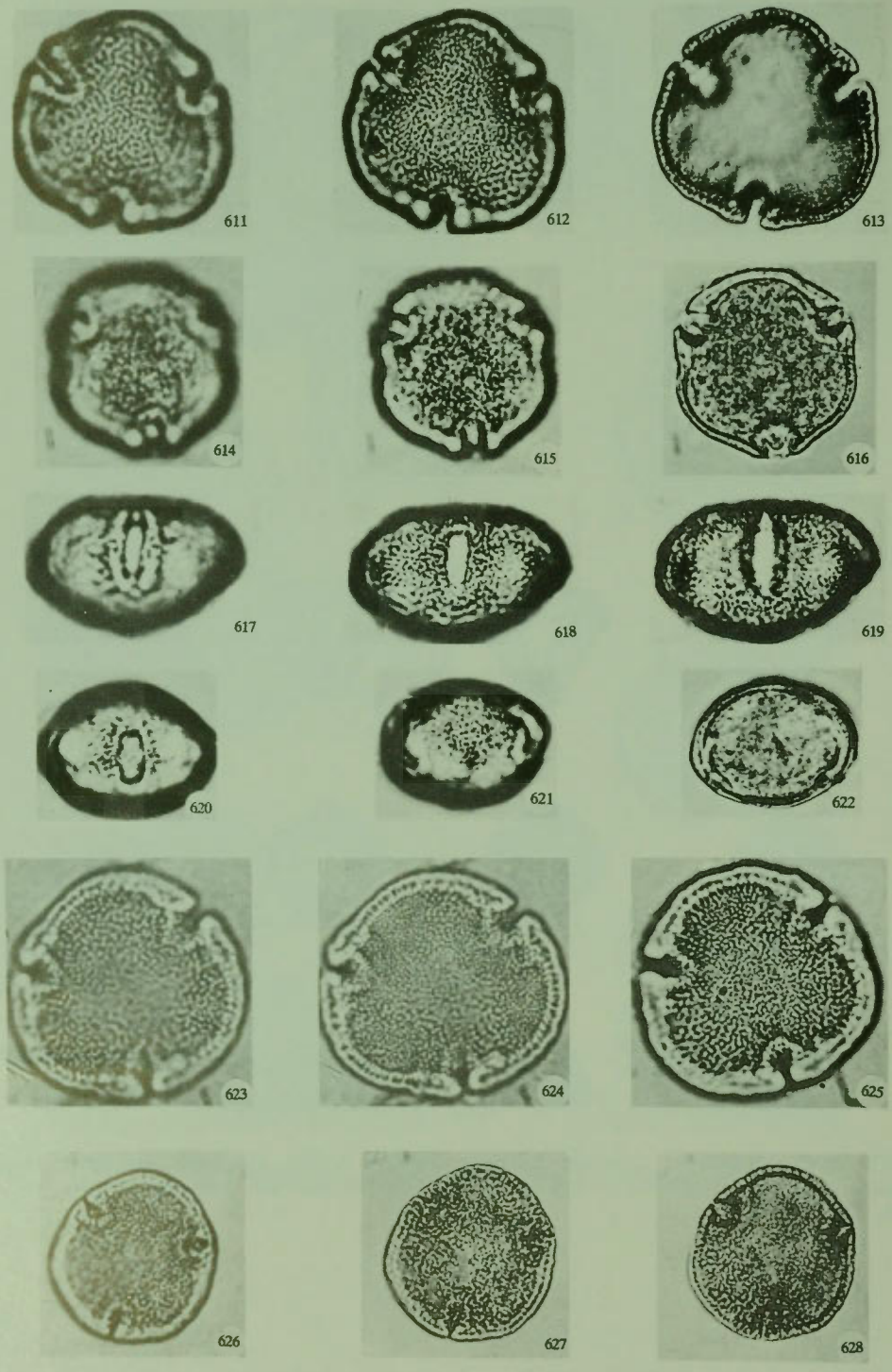
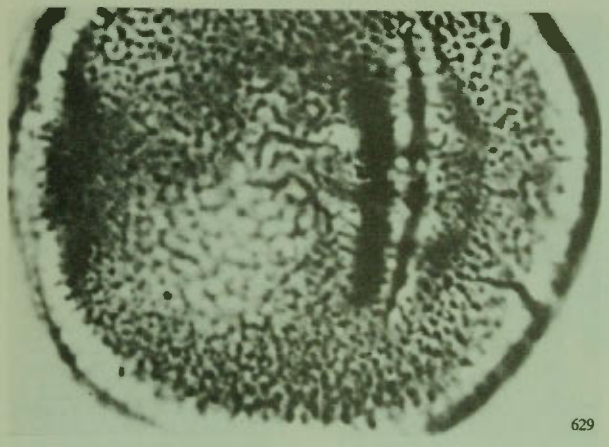
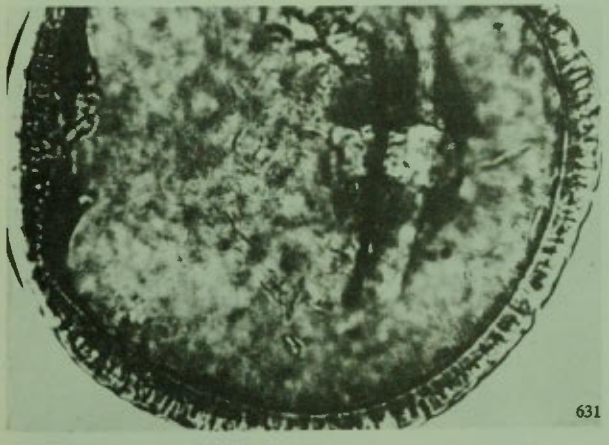


PLATE 30. Tiliaceae: *Brownlowia argentata* 611–613 and 617–619, x 1000, acetolysed; 614–616 and 620–622, x 1000, Wodehouse technique. *Brownlowia tersa* 623–625, x 1000, acetolysed; *Brownlowia elata* 626–628, x 1000, acetolysed.





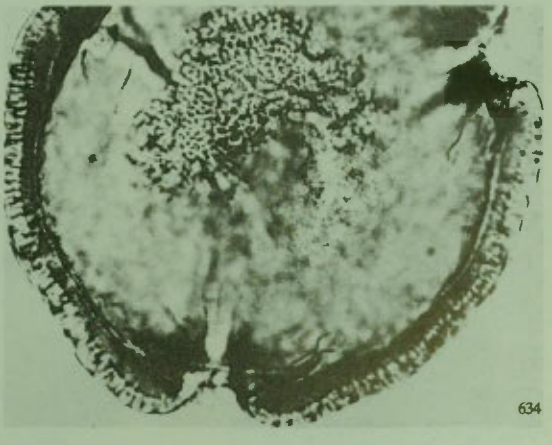
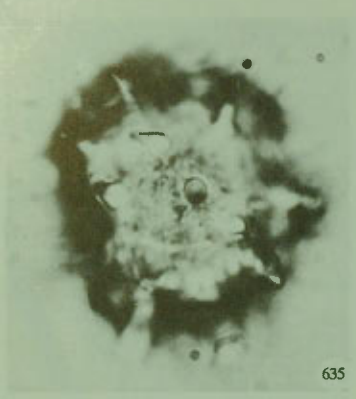


PLATE 31. Pellicieraceae: *Pelliciera rhizophorae* 629–634, x 1000, acetolysed.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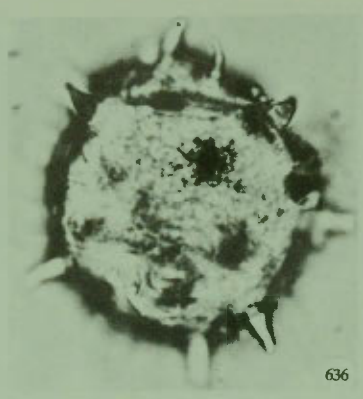
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PLATE 32. Bombacaceae: *Camptostemon philippinensis* 635–637, x 1000, Wodehouse technique; 638–643, x 1000, acetolysed.

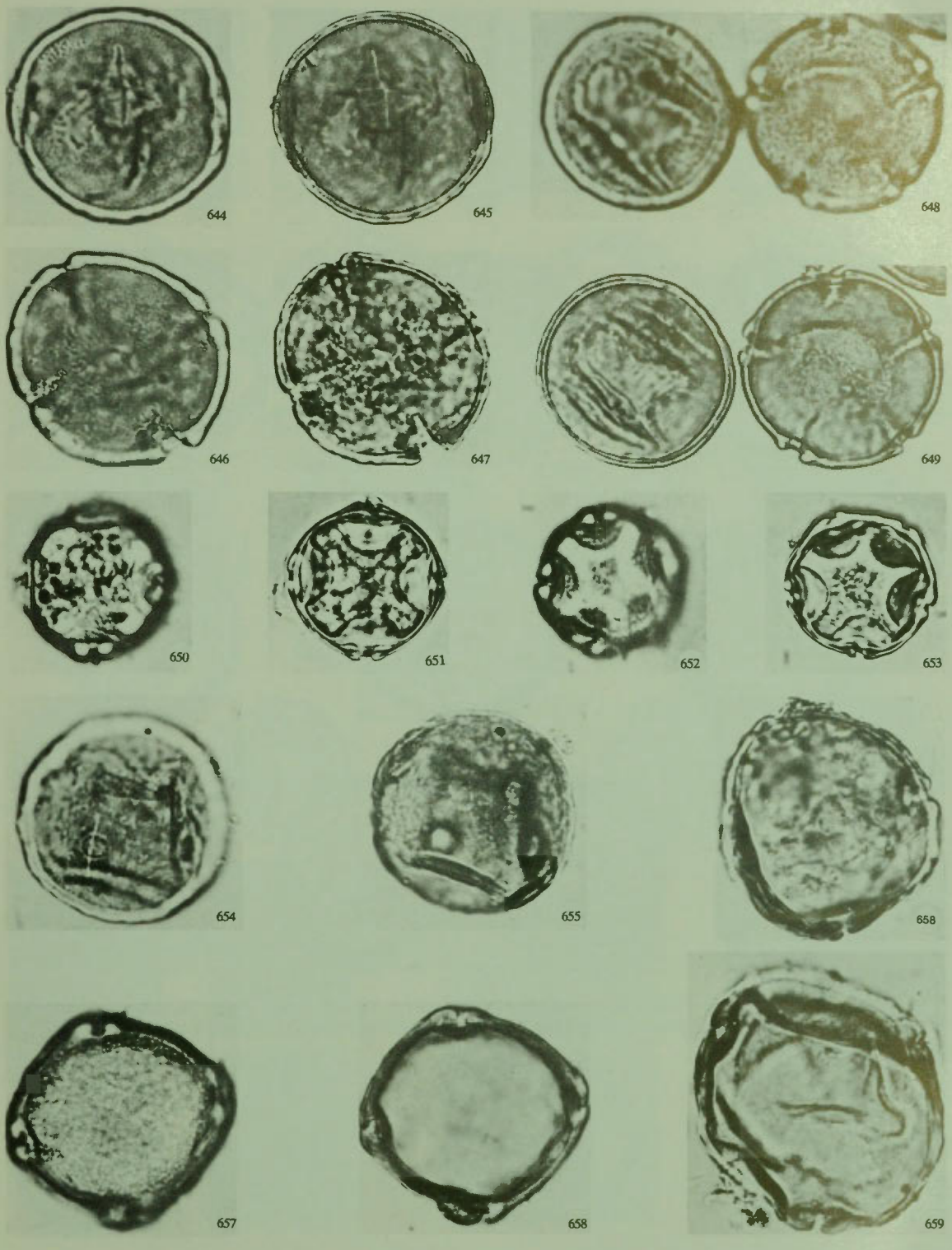


PLATE 33. Meliaceae: *Xylocarpus australasicus* 644–649, x 1000, acetolysed; 648–649: tetra and pentacolporate grains; 650–653, x 1000, Wodehouse technique, tetra and pentacolporate grains. *Xylocarpus granatum* 654–659, x 1000, acetolysed; 659: tricolporate grain.

PLATE 34. Meliaceae: *Xylocarpus mekongensis* 660–661, x 1000, acetolysed; 662–663, x 1000, Wodehouse technique; 663: pentacolporate grain. *Xylocarpus moluccensis* 664–673, x 1000, acetolysed (3, 4 and 5 colporate grains).

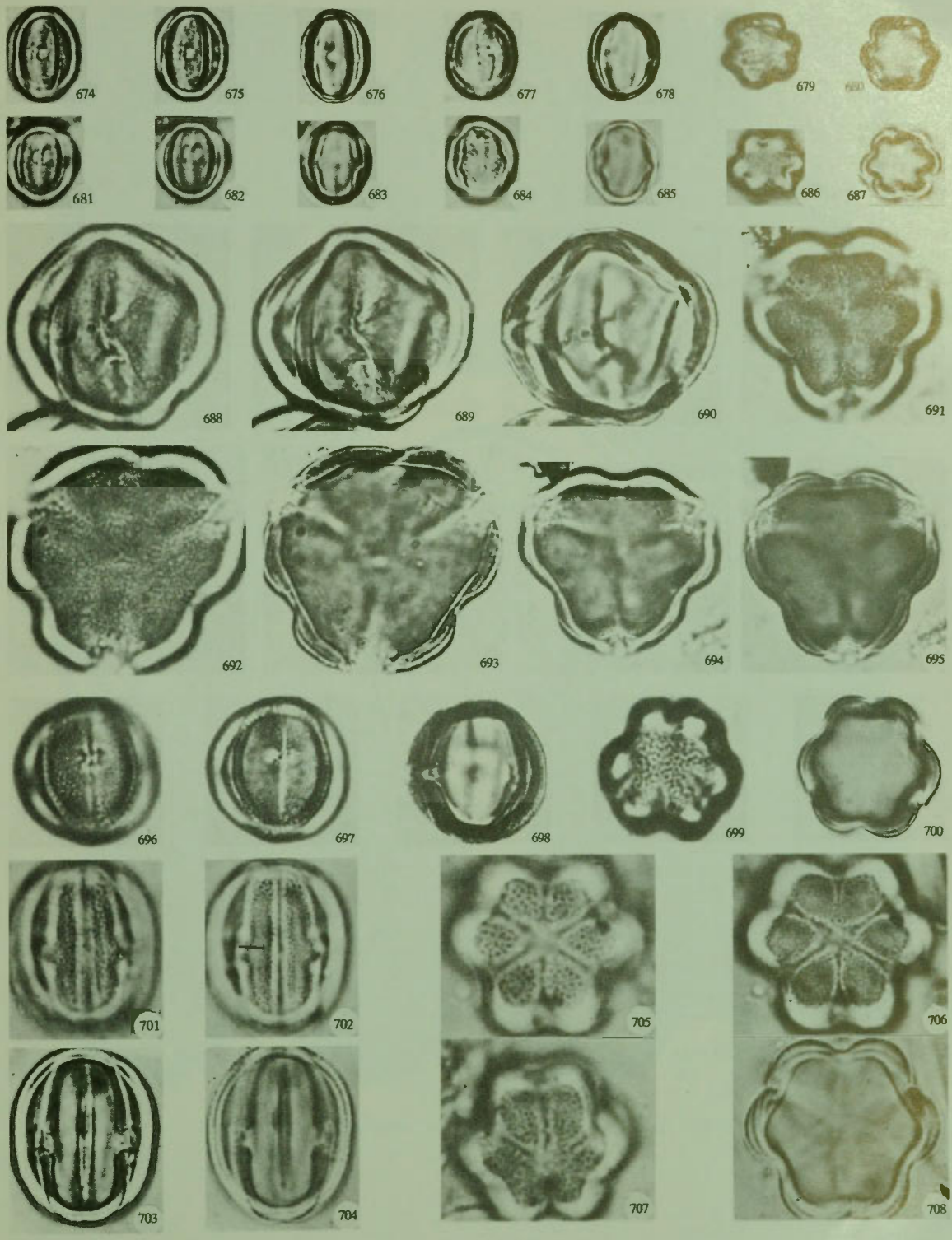


PLATE 35. Combretaceae: *Conocarpus erectus* 674–687, x 1000, acetolysed. *Lumnitzera littorea* 688–695, x 1000, acetolysed. *Lumnitzera racemosa* 696–708, x 1000, acetolysed.

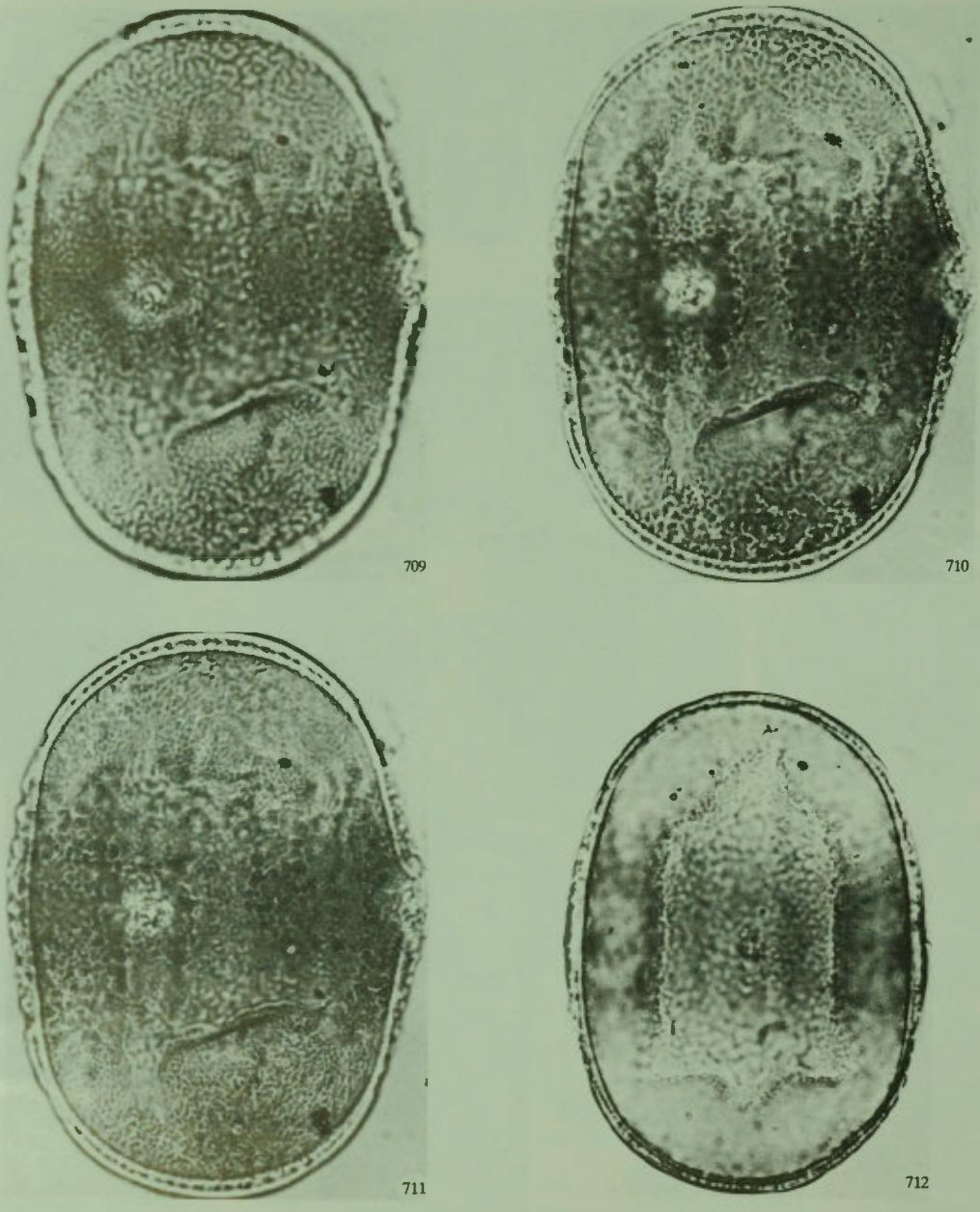


PLATE 36. Sonneratiaceae: *Sonneratia alba* 709–712, x 1000, acetolysed.

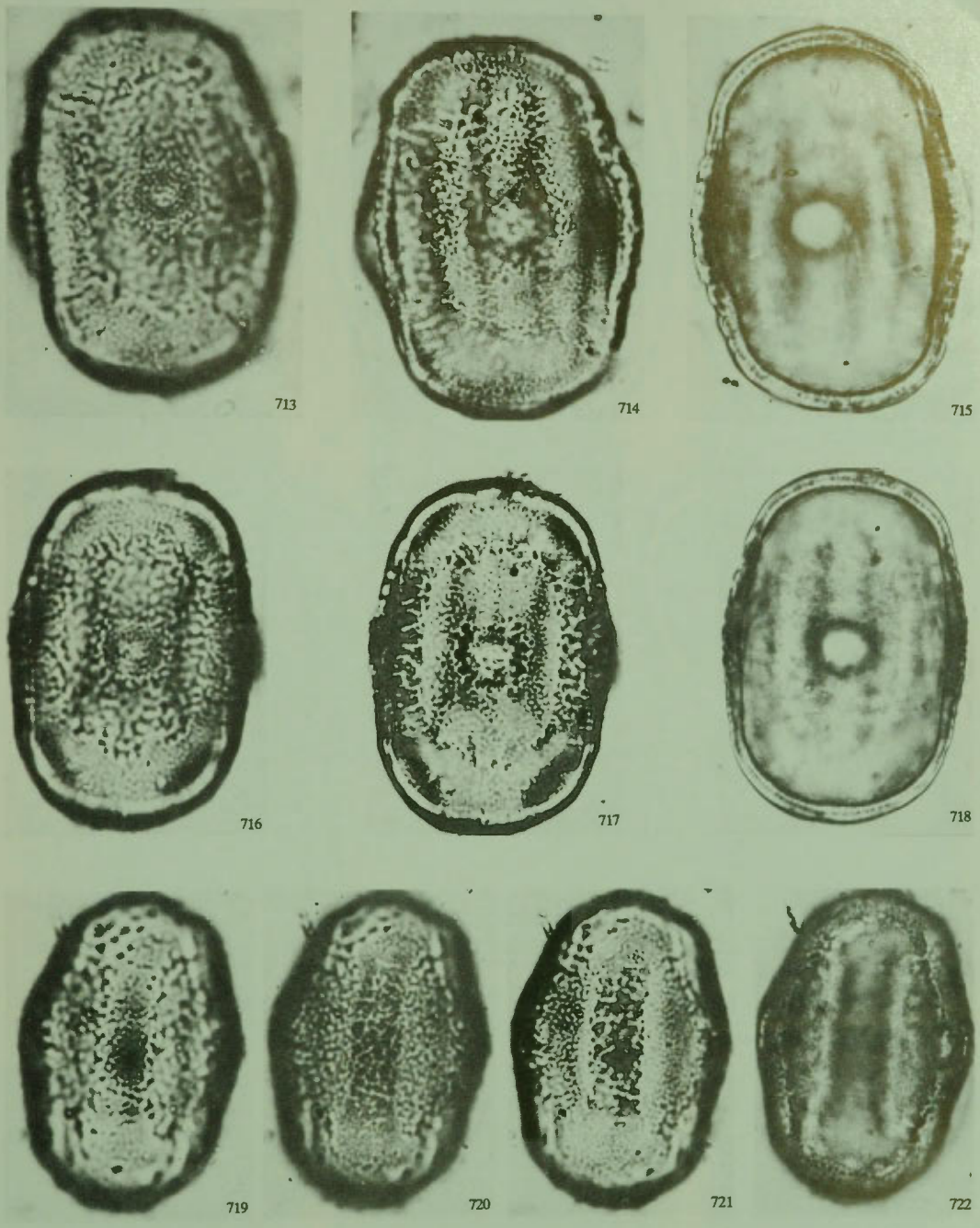
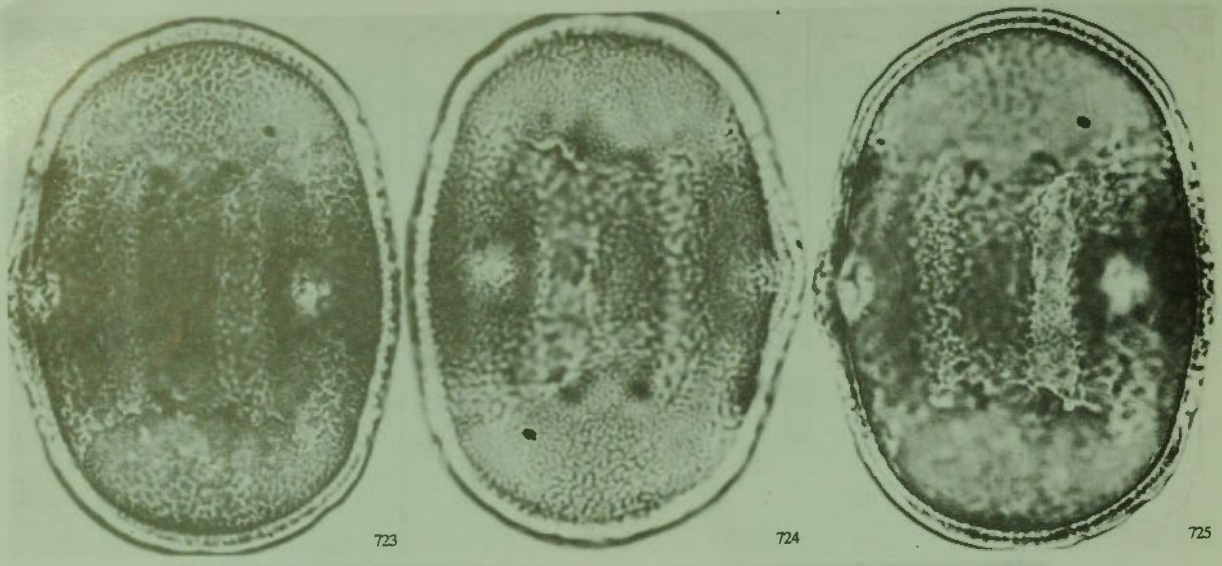


PLATE 37. Sonneratiaceae: *Sonneratia alba* 713–722, x 1000, acetolysed.



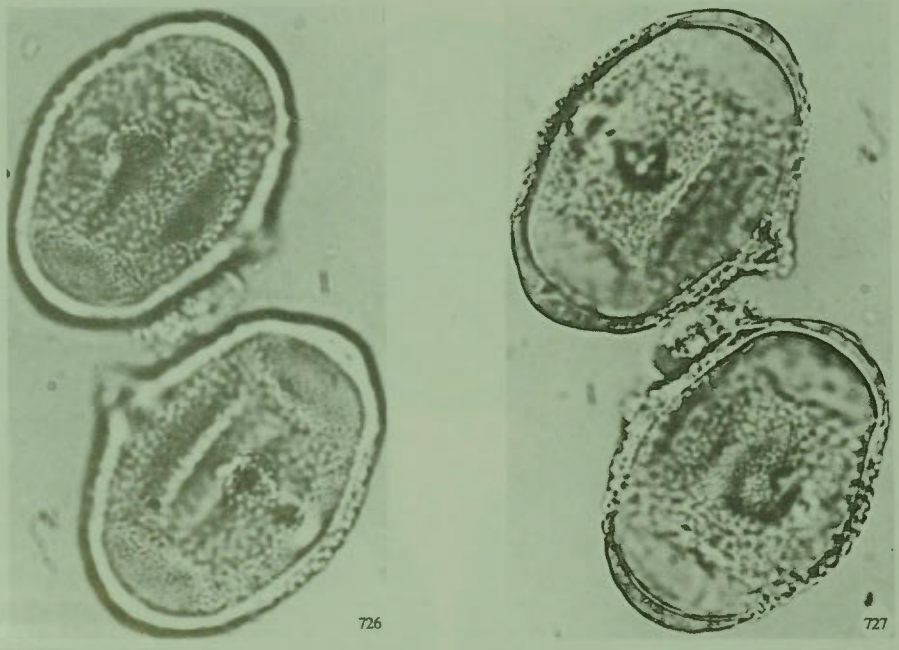


PLATE 38. Sonneratiaceae: *Sonneratia alba* 723–725, x 1000, acetolysed. *Sonneratia alba* x *caseolaris*, 726–727, x 1000, acetolysed. *Sonneratia alba* x *ovata*, 728–730, x 1000, acetolysed.

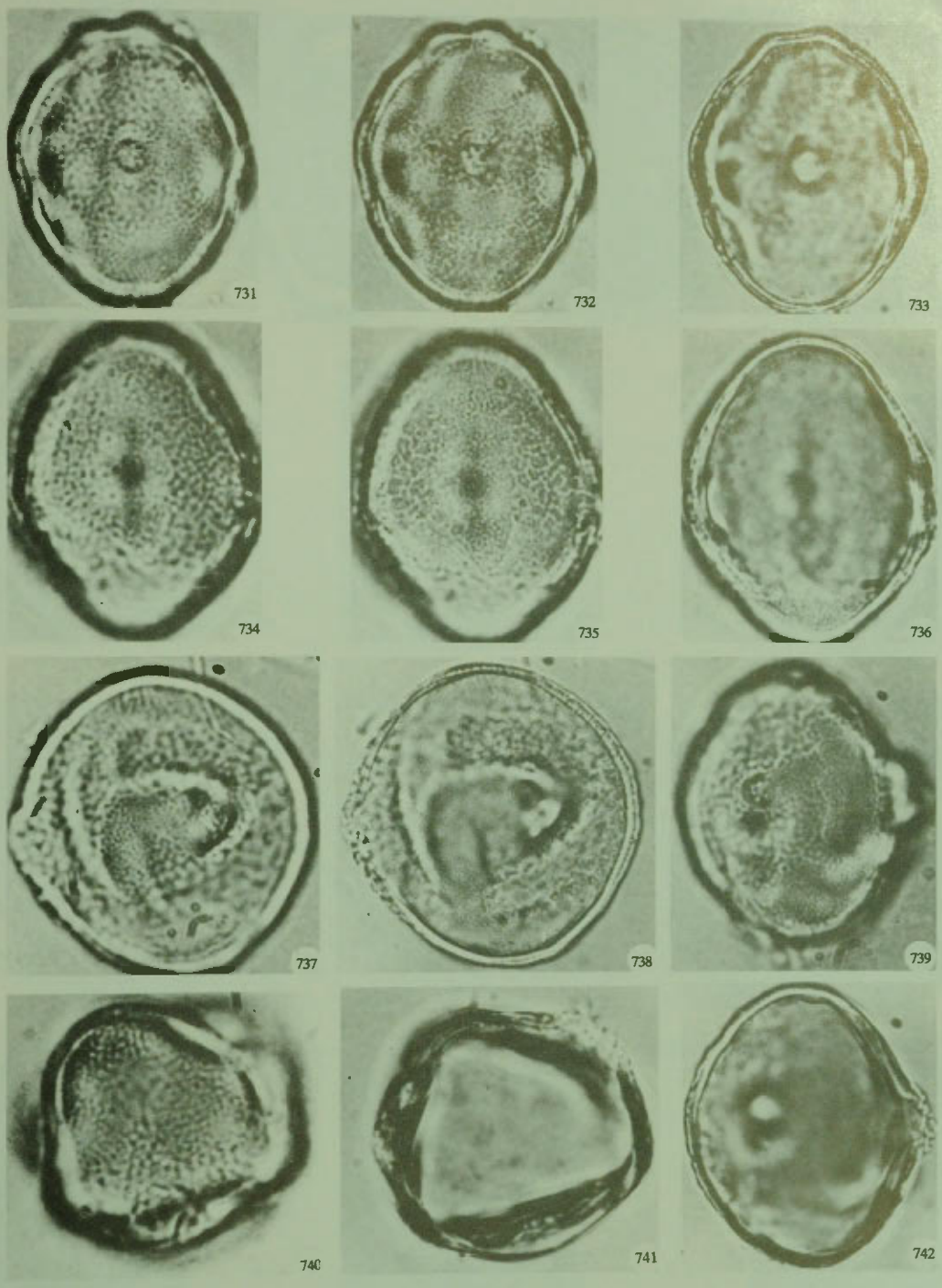


PLATE 39. Sonneratiaceae: *Sonneratia griffithii* 731–742, x 1000, acetolysed.

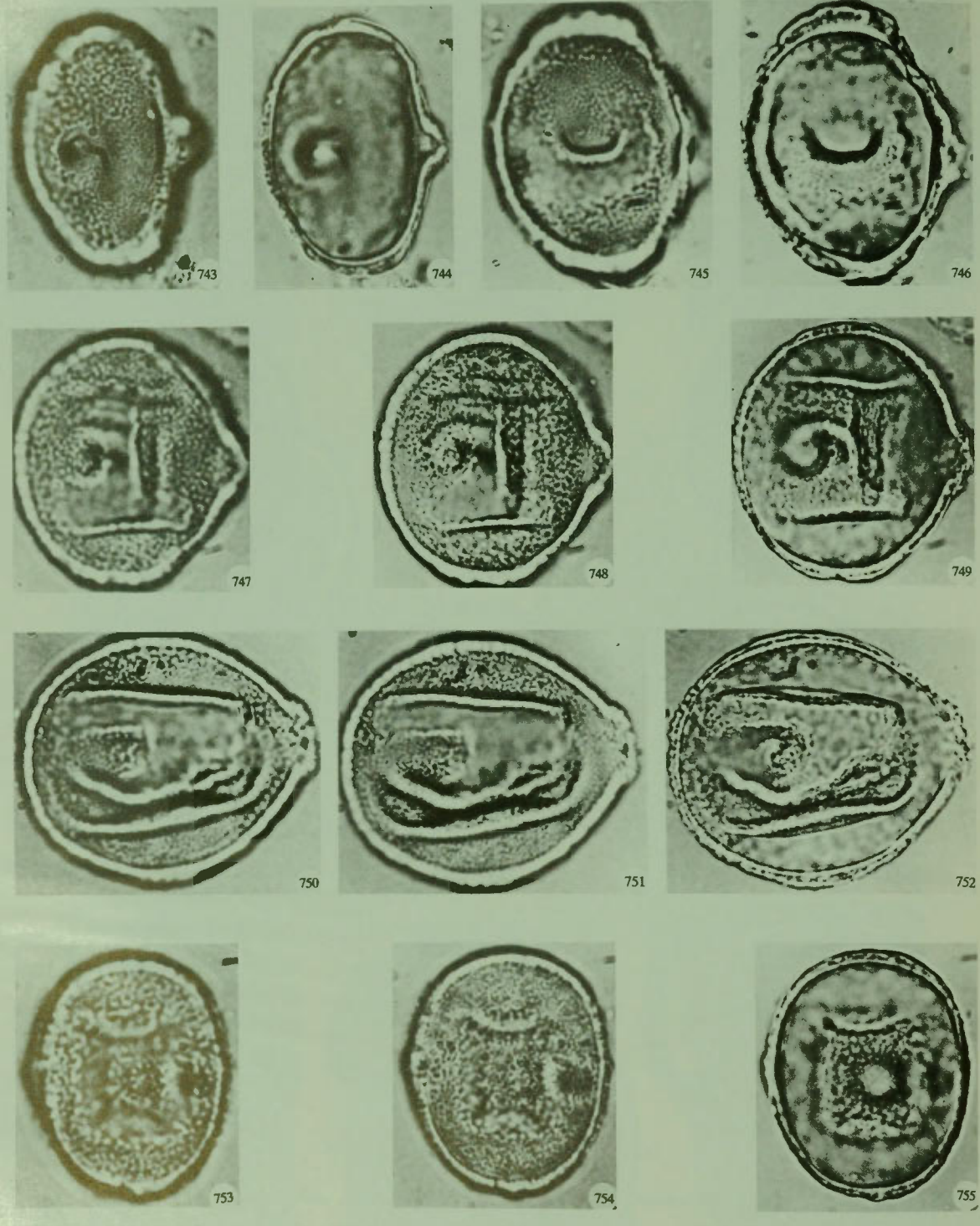


PLATE 40. Sonneratiaceae: *Sonneratia ovata* 743–755, *x* 1000, acetolysed; 745–746: abnormal grain.

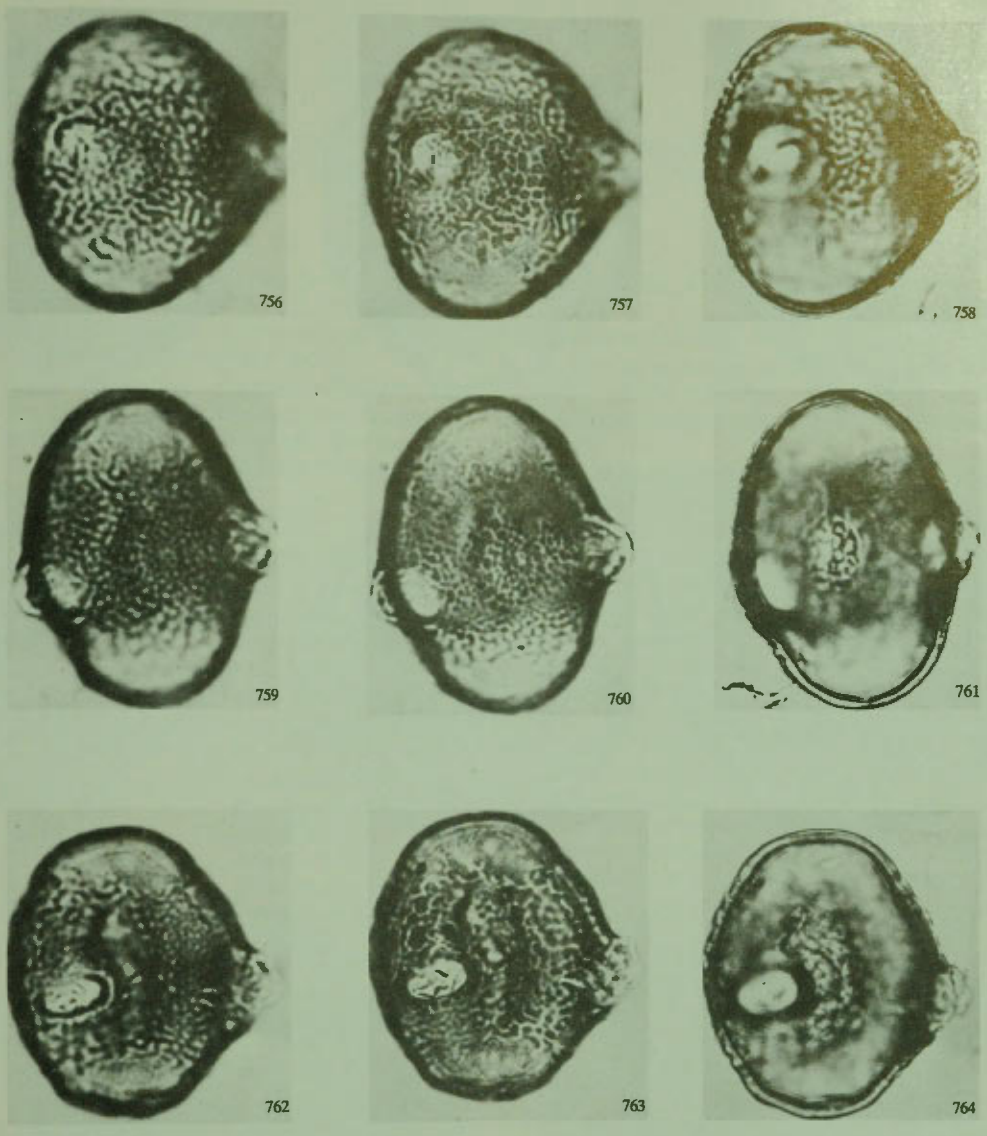


PLATE 41. Sonneratiaceae: *Sonneratia caseolaris* 756–764, x 1000, acetolysed.

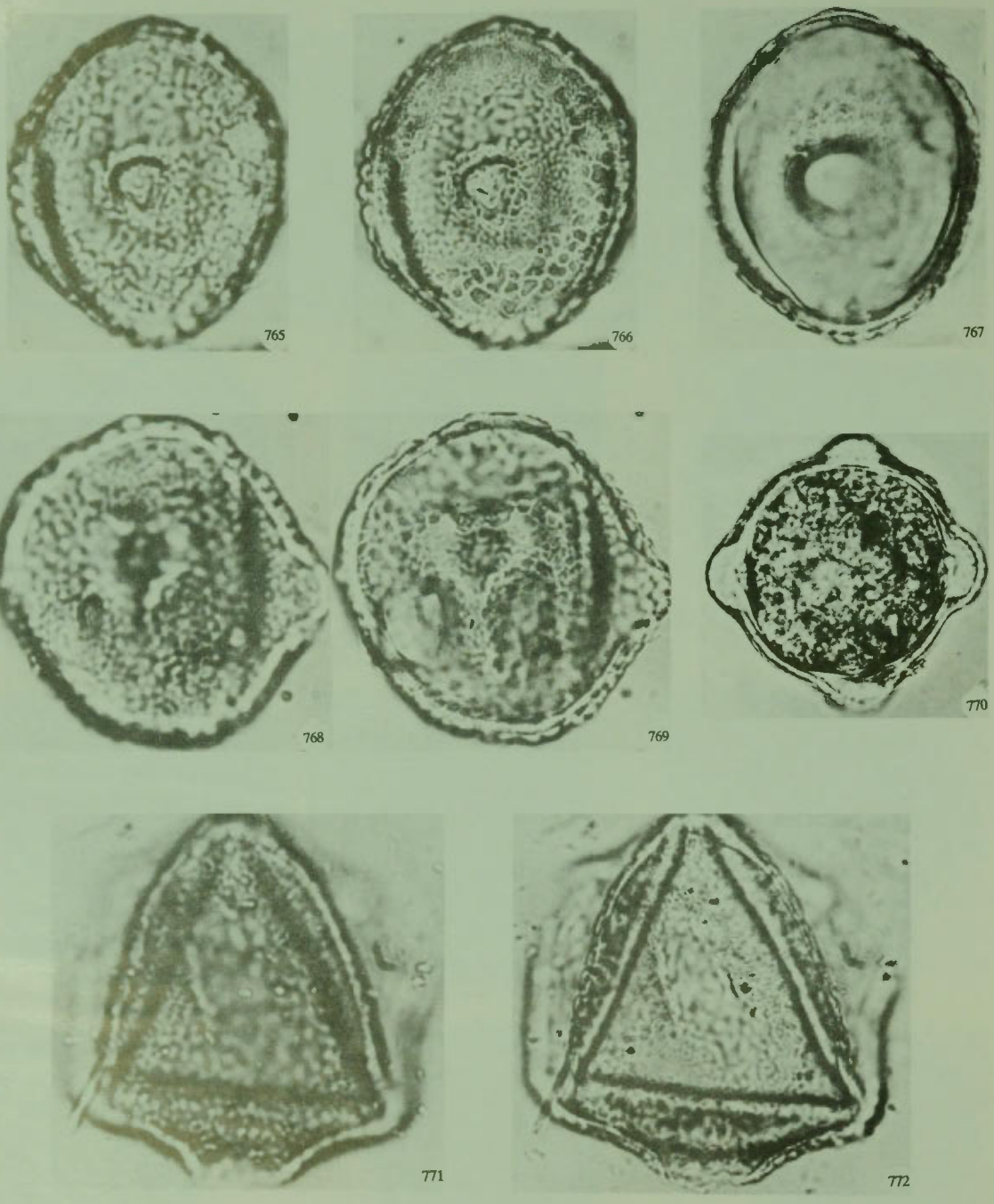


PLATE 42. Sonneratiaceae: *Sonneratia apetala* 765–769 and 771–772, x 1000, acetolysed; 770, x 1000, Wodehouse technique, abnormal grain, tetraaperturate.

DISSEMINATION AND SEDIMENTATION OF MANGROVE POLLEN SPORES AND MARINE MICROPLANKTON

To attain a reasonable degree of accuracy in the palynological reconstruction of palaeoenvironments, a knowledge of the following conditions is very useful:

1) the ecological requirements of the extant genera corresponding to fossil pollen;

2) the relationships between the vegetation and the palynological assemblage preserved in recent sediments.

Recent mangrove sediments

Some important works dealing with palynological analyses of surface sediment samples collected in various geographical sites around the world provide data on the relationships within the mangrove community. Among them may be mentioned:

Australia	Grindrod (1985)
Cameroon	Boyé *et al.* (1975)
Florida	Riegel (1965)
Gabon	Aoutin (1967)
India	Caratini *et al.* (1973)
Indonesia	Caratini & Tissot (in press)
Malaysia (Sarawak)	Anderson & Muller (1975).

An example from one of these studies (Caratini *et al.*, 1973) is given briefly below.

Pichavaram (India)

In the mangroves of Pichavaram, at the mouth of the Cauvery delta, three main vegetation zones can be presently recognized (Fig. 5):

- *Rhizophora* zone with *Bruguiera cylindrica* and *Ceriops decandra*;
- *Avicennia marina* zone;
- back mangroves with *Suaeda,* stunted non-fruiting *Avicennia marina* and *Excoecaria agallocha.*

Pollen analysis of the surface samples from these three zones gives a picture of a vegetation that is not fundamentally different from the recent floristic composition (Fig. 6). This deviation is mainly due to:

- over-representation of Rhizophoraceae and *Sonneratia*;
- normal representation of *Suaeda*;
- under-representation of *Avicennia* and other mangrove taxa such as *Excoecaria agallocha, Acanthus ilicifolius, Lumnitzera racemosa*; ...
- presence of allochthonous pollen belonging to hinterland flora which constitutes nearly 25% of the total pollen grains extracted from the sediments.

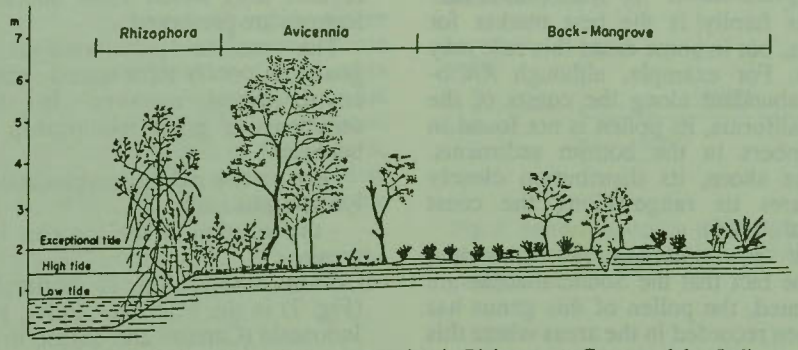


Fig. 5. Zonation of the mangrove vegetation in Pichavaram, Cauvery delta, India (from Blasco and Caratini, 1973).

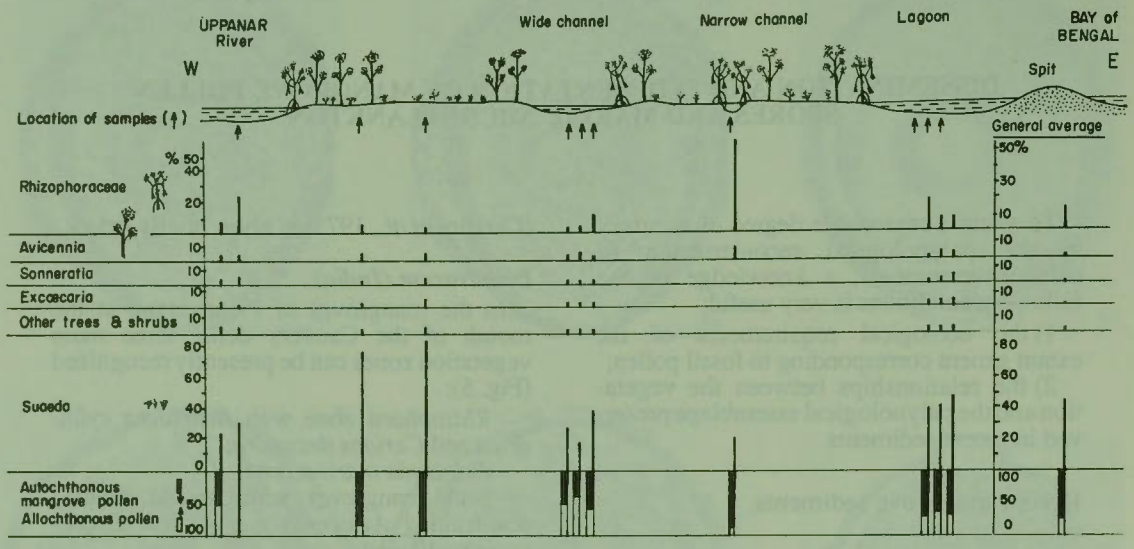


Fig. 6. Relationship between mangrove vegetation and palynology of surface sediments in Pichavaram (from Caratini et al., 1973).

Marine sediments

The sedimentation of mangrove pollen and spores in recent marine deposits has also been investigated offshore several areas :

Orinoco delta	Muller (1959)
Gulf of California	Cross *et al.* (1966)
Ivory Coast	Caratini *et al.* (in press)

From these studies, the most striking data concerning the degree of representativity of pollen in the sediments are as follows:

over-representation of Rhizophoraceae. Hence this family is the best marker for mangroves, but in some cases this rule may not apply. For example, although *Rhizophora* is abundant along the coasts of the Gulf of California, its pollen is not found in large numbers in the bottom sediments. Nearer the shore, its distribution closely approximates its range along the coast (Cross *et al.*, 1966).

- *normal representation of Sonneratia.* Despite the fact that the Sonneratiaceae are bat-pollinated, the pollen of this genus has always been recorded in the areas where this family is represented.

under-representation of Avicennia and Nypa.

Marine microplankton

The palynomorphs with a marine origin often occur in mangrove sediments.

Among the Dinoflagellates kystes, most frequent are *Operculodinium centrocarpum, Hemicystodinium zoharii* and *Spiniferites sp.* Foraminifera are also recorded but they can not be identified with accuracy because after the palynological processing only their organic tests which show no characteristic features are preserved.

The marine palynomorphs, although generally poorly represented , may be useful environmental markers. In the surface sediments, a good relationship does exist between :

- the marine palynomorphs/continental palynomorphs ratio;
- the location of the samples in the mangrove.

This relationship is particularly clear (Fig. 7) in the Mahakam delta, Kalimantan, Indonesia (Caratini and Tissot, in press).

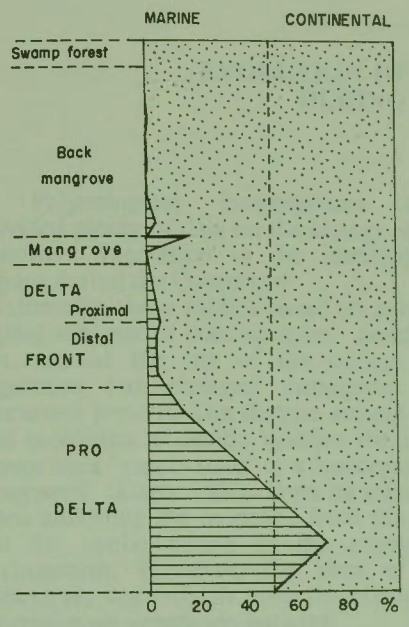


Fig. 7. Mahakam delta, Kalimantan: Schematic representation of the ratio between marine and continental palynomorphs in surface samples collected from the apex of the delta (top of the diagram) to its offshore part (bottom of the diagram).

Aeropalynology

Although dissemination of pollen and spores by wind is the first step towards sedimentation, not much data are available concerning the aeropalynology of mangrove pollen taxa.

Offshore Senegal and Gambia where mangrove forests are found along some parts of the coast and along the Gambia river, a pollen trap was exposed during the oceanographic cruise ORGON III (Caratini and Cour, 1980). The pollen of *Rhizophora*, the only mangrove pollen genus recorded, constitutes 1.91% of the total airborne pollen.

In Indonesia, within and offshore the Mahakam delta (Kalimantan), three aeropalynological samples were investigated during the MISEDOR borewell drilling (Caratini and Tissot, in press).

Such a limited study is not sufficient for drawing conclusions, but the following features (Fig. 8) may be mentioned:

- Rhizophoraceae: as expected, this family has the best representation, attaining 58.5% offshore where the only mangrove pollen recorded is *Ceriops*;
- *Nypa*: the greater part of the deltaic plain is called "*Nypa* plain" because it is covered by about 99% of *Nypa fruticans*. Although these palms produce flowers throughout the year, only one pollen grain of *Nypa* was trapped. This species may be considered as entomophilous which may explain the consistently low percentage of *Nypa* pollen found in the Holocene and recent sediments.
- *Sonneratia*: the very low percentages of *Sonneratia* (0.4 and 0.8%) are not in accordance with the surrounding vegetation where *Sonneratia* is common nor with the rather frequent occurrence of the pollen of this genus generally observed in estuarine and marine sediments.
- the under-representation of other mangrove or back-mangrove species, already noticed in surface sediments, is confirmed.

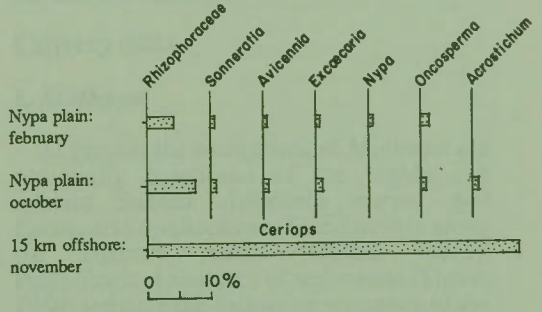


Fig. 8. Aeropalynology in the Mahakam delta, Kalimantan, Indonesia (data from Caratini & Tissot, in press).

EVOLUTION OF MANGROVE VEGETATION DURING THE QUATERNARY

Palynological investigations have provided plenty of data on the history of the mangrove vegetation in the intertropical regions during the Quaternary.

Generally, these studies based on palynological analysis of core samples, conclude that, around the site of the coring, the vegetation has changed throughout the concerned periods. The dispute among present ecologists to decide whether the mangroves are a "steady state" or a "successional ecosystem" (Lugo, 1980) loses its meaning when analysing the evidence from the past and the cyclic nature of the mangrove environment. However, the aims of the authors are not only to trace the history of the mangrove vegetation but also:

1) to reconstruct the evolution of the palaeoenvironments;

2) to identify, eventually, the external factors responsible for the changes with attempts at their quantification.

In fact, there are several external factors which maintain the mangroves under stressing conditions. Among them, are factors related to:

- *water*: salinity, fresh water supply, temperature, energy *i.e.* tidal flows, storms, currents,etc;
- *relative sea level changes*: geomorphology, sedimentation rates,...
- *climate* on which depend temperature, fresh water supply, salinity,...
- *human activity* which, although recent has a strong (and unfavourable) influence.

All these factors are more or less strongly interlinked. However, as the mangrove forests are always located at the ocean-continent interface, they are directly related to changes in the sea level, *i.e.* they mostly depend on global events. Local factors may also have an influence on the nature and development of mangrove forests. However, during the Quaternary, the glacial fluctuations which dominated sea level changes, have consequently affected the fate of the mangroves as shown in the following survey of the reconstruction of mangrove history in the tropics during this period.

INDIAN SUBCONTINENT

The vegetation maps (Gaussen *et al.*, 1961-1978) and the monograph on the mangroves of India by Blasco (1975), as also the bibliography on Indian mangroves (Untawale *et al.*, 1976) give a fair picture of the present state of the mangrove vegetation in India. Using the pollen morphological descriptions of tropical Asian plants, particularly those published by Guinet (1962), it has been possible to identify the palynological elements found in recent and fossil sediments and to trace the evolution of mangroves in some localities (Fig. 9). In most of the investigated sites, a severe degradation of the mangrove vegetation due to anthropic pressure has been noticed during the last few centuries.

Cauvery delta

1. *Muthupet*

At present the mangroves of Muthupet are essentially composed of the highly salt tolerant *Suaeda*. *Avicennia marina* and *Excoecaria agallocha* are found mainly along the channel banks (Blasco, 1975). Palynological analyses of sediments (Tissot, 1980) indicate the following sequence of the vegetation during the last two millennia (Fig. 9):

- periods A and B: establishment and extension of *Avicennia*, *Excoecaria* and *Suaeda*;
- period C: increase in *Avicennia*;
- period D: *Avicennia* now being replaced by *Excoecaria* and *Suaeda* .

The evolution of the mangrove vegetation and its deterioration during the last stages are due to natural evolution. The heavy sedimentation supplied by the Cauvery induces a progradation process and the seaward shifting of the shoreline. Hence, the increasing distance between the drilling site and the seashore is reflected by variations in the percentages of marine microfossils along the core.

2. Pichavaram

It is estimated that the mangrove sediments of Pichavaram are not more than 1500 years old (Tissot, 1980), on the basis of the rate of sedimentation calculated since the first occurrence of*Casuarina* pollen (introduced in India about two centuries ago) in the sediments and radiocarbon dating near the site of the cores. Three phases are recognized in the palynological evolution of the Pichavaram vegetation (Fig. 9):

1) phase A, the deepest: establishment of the mangrove vegetation;

2) phase B: extension of *Avicennia*, *Rhizophora*, *Sonneratia* and *Excoecaria*,

3) phase C: phase of gradual elimination of *Sonneratia*.

Recent ecological studies show that there is very little regeneration in the *Avicennia marina* zone. Along the water's edge, *Avicennia officinalis* is mostly represented by old trees with a feeble rate of reproduction. It is well on the way to disappearing and its place is being taken by *Avicennia marina*. Likewise, *Lumnitzera* also seems to be vanishing since it has become quite rare and its regeneration is rather limited. Further, the mangrove area is getting reduced because of encroachment by the sea on one hand and sand on the other (Kerrest, 1980). There is also considerable human interference, as shown by palynological analysis (Tissot, 1980). One of the most important causes is the damming in the hinterland which induces soil hypersalinity and a drastic selection of species able to withstand these extreme edaphic conditions. Hence urgent measures should be taken to conserve this mangrove (Meher-Homji, 1985).

Godavari delta

In the Godavari region, about 13,000 hectares are said to be covered by mangroves but a greater part of this is constituted by bushy thickets of *Avicennia*, *Sonneratia* and *Rhizophora* intermixed with recruits from the hinterland. Two core samples from this locality were analysed palynologically. In one of the cores (Balasudippa, Fig. 9),from a site near the sea, there is the constant presence of mangrove and marine elements such as Microforaminifera and Dinoflagellates. In the other site (Bairavapalayam, Fig. 9), far from the sea, the palynological assemblages are characteristic of a back-mangrove with less mangrove pollen; marine elements are rare and Chenopodiaceae are well developed.

The presence of *Casuarina* throughout the core offers an interesting chronological marker. It is quite likely that these pollen come from the *Casuarina* plantations in this region, which do not appear to be more than 50 years old. The old light-house, now situated about a dozen kilometres inland, also attests to the rapid sedimentation of this delta. As the pollen analyses show very little vegetational changes, it is inferred that the degradation of the local mangroves must have begun at least a few decades ago (Caratini *et al.*, 1980).

Brahmani delta

In Kalibhanja Dian Island, bathed by the Dhamra river, there are patches of degraded mangroves in the form of thickets. No distinct zonation is seen in this region where the flora consists of *Avicennia officinalis*, *Sonneratia apetala*, *Bruguiera gymnorrhiza*, *Phoenix paludosa*, *Excoecaria agallocha*, *Kandelia candel*, *Aegiceras corniculatum*, *Heritiera fomes*, *Xylocarpus spp.*, and several species from the hinterland.

Two cores from this region were analysed palynologically (Caratini *et al.*, 1980). They seem to be of a relatively recent age and offer no trace of change in the local vegetation which seemed to have been already greatly disturbed prior to the deposition of

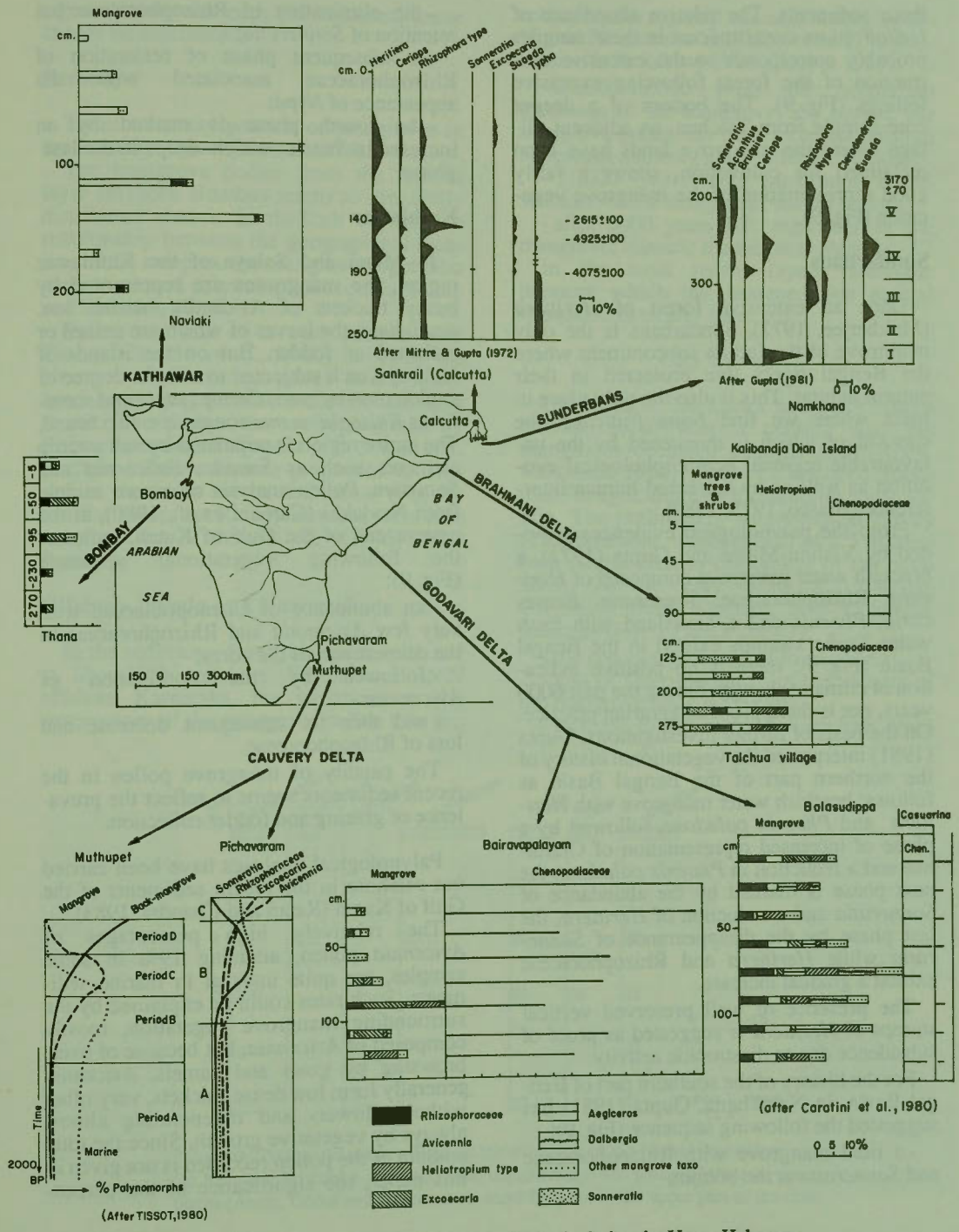


Fig. 9. Evolution of mangrove vegetation in India during the Upper Holocene.

these sediments. The relative abundance of *Heliotropium curassavicum* in these samples probably corresponds to the extensive destruction of the forest following excessive fellings (Fig. 9). The bottom of a deeper core sample from Talchua, an adjacent village where the mangrove lands have been reclaimed for cultivation, shows a fairly good representation of the mangrove vegetation (Fig. 9).

Sundarbans

Once an extensive forest of *Heritiera* (Mukherjee, 1972), Sundarbans is the only mangrove of the Indian subcontinent where the Bengal tigers live protected in their natural habitat. This is also the only place in India where we find *Nypa fruticans*, the survival of which is threatened by the unfavourable regional geomorphological evolution as well as by increased human interference (Blasco, 1975; 1980).

From the palynological evidences provided by Vishnu-Mittre and Gupta (1972), a brackish water mangrove composed of *Heritiera*, Rhizophoraceae, *Sonneratia*, *Excoecaria, Phoenix* and a hinterland with fresh water *Typha* swamps existed in the Bengal Basin (Fig. 9); there is no positive indication of climatic changes during the past 6000 years, nor is there proof of agrarian practice. On the basis of further investigations, Gupta (1981) interpreted the vegetational history of the northern part of the Bengal Basin as follows: brackish water mangrove with *Heritiera* and *Phoenix paludosa*, followed by a phase of increased representation of Graminae and a reduction in *Phoenix paludosa*; the next phase is marked by the abundance of *Sonneratia* and a reduction of *Heritiera*, the last phase by the disappearance of *Sonneratia* while *Heritiera* and Rhizophoraceae exhibit a gradual increase.

The presence of well preserved vertical stumps of *Heritiera* is suggested as proof of subsidence due to diastrophic activity.

For the history of the southern part of Bengal Basin, in Namkhana, Gupta (1981) has suggested the following sequence (Fig. 9):

- a tidal mangrove with Rhizophoraceae and *Sonneratia* at the bottom;
- the elimination of Rhizophoraceae but retention of *Sonneratia*;
- a subsequent phase of restoration of Rhizophoraceae associated with the appearance of *Nypa*;
- the fourth phase is marked by an increase in *Sueda* which drops in the last phase.

Kathiawar

In Miani and Salaya of the Kathiawar region, the mangroves are represented by bushy thickets of *Avicennia marina* var. *acutissima*, the leaves of which are grazed or collected as fodder. But on the islands of Gulf of Kutch subjected to a lesser degree of exploitation by man, *Ceriops tagal* and sometimes *Rhizophora mucronata* are also found. The entire region is populated by salt swamp elements such as *Suaeda*, *Salicornia* and *Sesuvium*. Pollen analysis of a core sample from Navlakhi (Caratini *et al.*, 1980), at the eastern end of the Gulf of Kutch, indicates the following vegetational sequence (Fig. 9):

- an abundance of Chenopodiaceae with very few *Avicennia* and Rhizophoraceae in the deepest part of the cores;
- followed by the domination of *Avicennia*;
- and then its subsequent decrease and loss of Rhizophoraceae.

The paucity of mangrove pollen in the recent sediments seems to reflect the prevalence of grazing and fodder collection.

Palynological analyses have been carried out offshore in the recent sediments of the Gulf of Kutch (Ratan and Chandra, 1983).

The relatively high percentages of *Avicennia* pollen, attaining 19% in some samples, are quite unusual in marine sediments. Such rates could be explained by the surrounding mangrove vegetation, mostly composed of *Avicennia*, but because of overbrowsing by goats and camels, *Avicennia* generally form low dense thickets, very often without flowers and regenerating almost always by vegetative growth. Since the total amount of the pollen recorded is not given in this paper, the significance of the percen-

tages obtained for each palynological taxon cannot be ascertained.

Bombay

There are many pockets of mangroves in the Bombay region (Blasco, 1975).

The mangrove pollen from the bottom layer offshore Bombay seems so irregularly distributed that it is difficult to draw a relationship between the geographical location of the samples, the mangrove vegetation and its induced palynological records (Ratan and Chandra, 1984).

Pollen analysis of a core sample near Thana (Caratini *et al.*, 1980) indicates the presence of *Casuarina* pollen at the lower level suggesting that the sediments are very recent. The mangroves are represented by Rhizophoraceae, *Avicennia* and *Sonneratia*. A slight increase in their proportion is noticed in the most recent sediments (Fig. 9). Similar values for Rhizophoraceae were also reported by Vishnu-Mittre (1975) near Bombay.

Offshore Kerala and Karnataka

In the sediments from two cores collected at about10°N offshore Kerala and 15°N offshore Karnataka, the variations in the percentages of the mangrove pollen taxa are related to the regional climatic history of the Upper Pleistocene and Holocene. The succession is as follows (Van Campo, 1983):

- 22,000-18,000 years BP: minimum extension of the mangrove; *dry period*. No mangrove pollen has been recorded offshore Karnataka and only a few offshore Kerala;
- 11,000 years BP: maximum representation of the mangrove : *humid period*;
- after 6000 years BP: regression of the mangrove; *climatic transition to Recent*.

In the most recent layers, anthropic pressure which has hastened this natural regression is clearly seen.

SRI LANKA

Old maps of Sri Lanka and place names provide proof that a century ago the mangroves occupied a larger area (Abeywickrama, 1964). Most of it has been reclaimed for agriculture or for building construction. The preliminary palynological survey (Thanikaimoni, unpublished) of a 5 m deep core sample (Radio carbon age of the basal 30 cm of the core being 820 ± 80 BP: GIF 5619) from Kalutara, near Colombo, indicates (Fig. 10 and Plate 43):

- the constant presence of *Rhizophora*;
- loss of *Oncosperma* from the vicinity of the mangrove since 600 years;
- increase in the weed *Acrostichum*, from

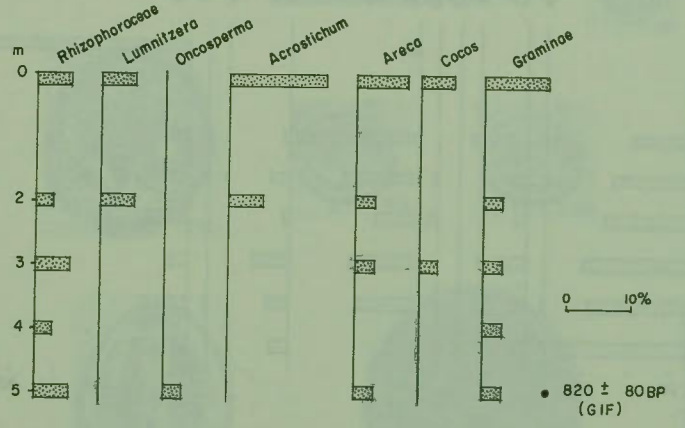


Fig. 10. Pollen diagram related to the evolution of the coastal vegetation at Kalutara, Sri Lanka (Thanikaimoni, unpublished). The pollen of the cultivated plants (Areca, Cocos and Graminae) is more frequent in the upper part of the core.

the turn of the last century when this region seems to have been reclaimed for the cultivation of *Cocos*, *Areca* and other crops.

It is noteworthy that the number of pollen grains of *Cocos*, *Areca* and Graminae is higher in the upper part of the sediments.

SOUTH EAST ASIA

Thailand (Satingpra)

The floristic composition of mangroves of Thailand has been studied by S. Aksornkoae (1979) and D. Banijbatana (1957).

Regarding their recent evolution, pollen analysis (Fig. 11) provides evidence of a former (2600 BP) mangrove composed of Rhizophoraceae, *Nypa*, *Avicennia* and *Excoecaria* in the archaeological site of Satingpra (Thanikaimoni, 1983). The hinterland was characterized by saline swamps with *Suaeda* and fresh water swamps with *Myristica* and the lowland forest of Dipterocarpaceae. The paucity of marine planktons and the relative abundance of fresh water swamp elements suggest that the site was originally a lagoon separated from the sea by a sandy spit populated with *Ipomoea*.

The palynological sequence indicates perceptible decrease in the mangrove vegetation probably due to human activity such as extraction of fuel wood, corroborated by the simultaneous quantitative increase of *Acrostichum*, a fern which grows in the cleared areas of the mangrove. The peak of human activity is registered in the sediment at –370 to –365 cm zone which is poor in pollen and spore content. Excessive felling might have resulted in the denudation of both the mangroves and the fresh water swamp forest. But subsequently there seems to have been an extensive reclamation of land for the cultivation of the traditional local rice. The local *Borassus* palm appears to have been planted on the bunds of the paddy fields. Effective drainage operations against excessive inundation seems to have adversely affected the mangrove site which, due to the increase in its salinity, seems to have yielded place to *Suaeda*.

Palynological data corroborate the array of archaeological evidences of significant human activity in the Satingpra region (Stargardt, 1976, 1977).

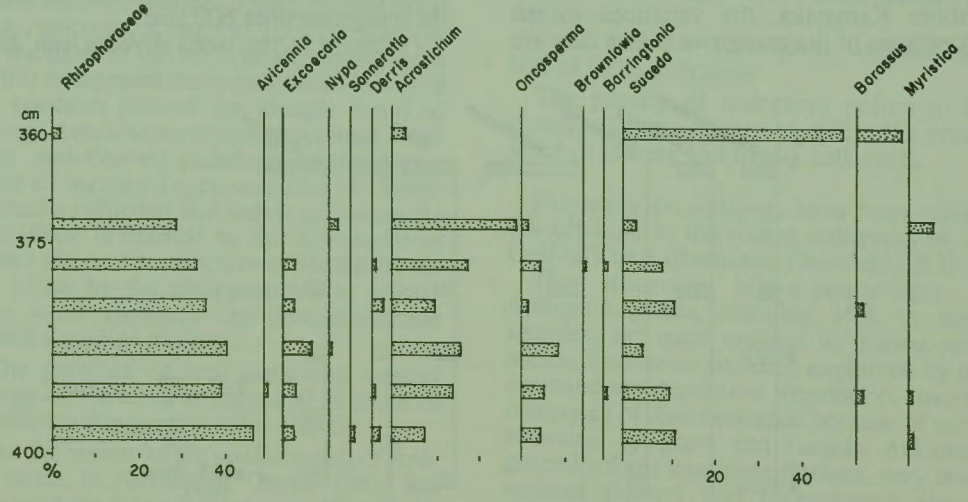


Fig. 11. Simplified pollen diagram of Satingpra, Thailand (from Thanikaimoni, 1983). Notice the decrease of mangrove taxa due to human activity.

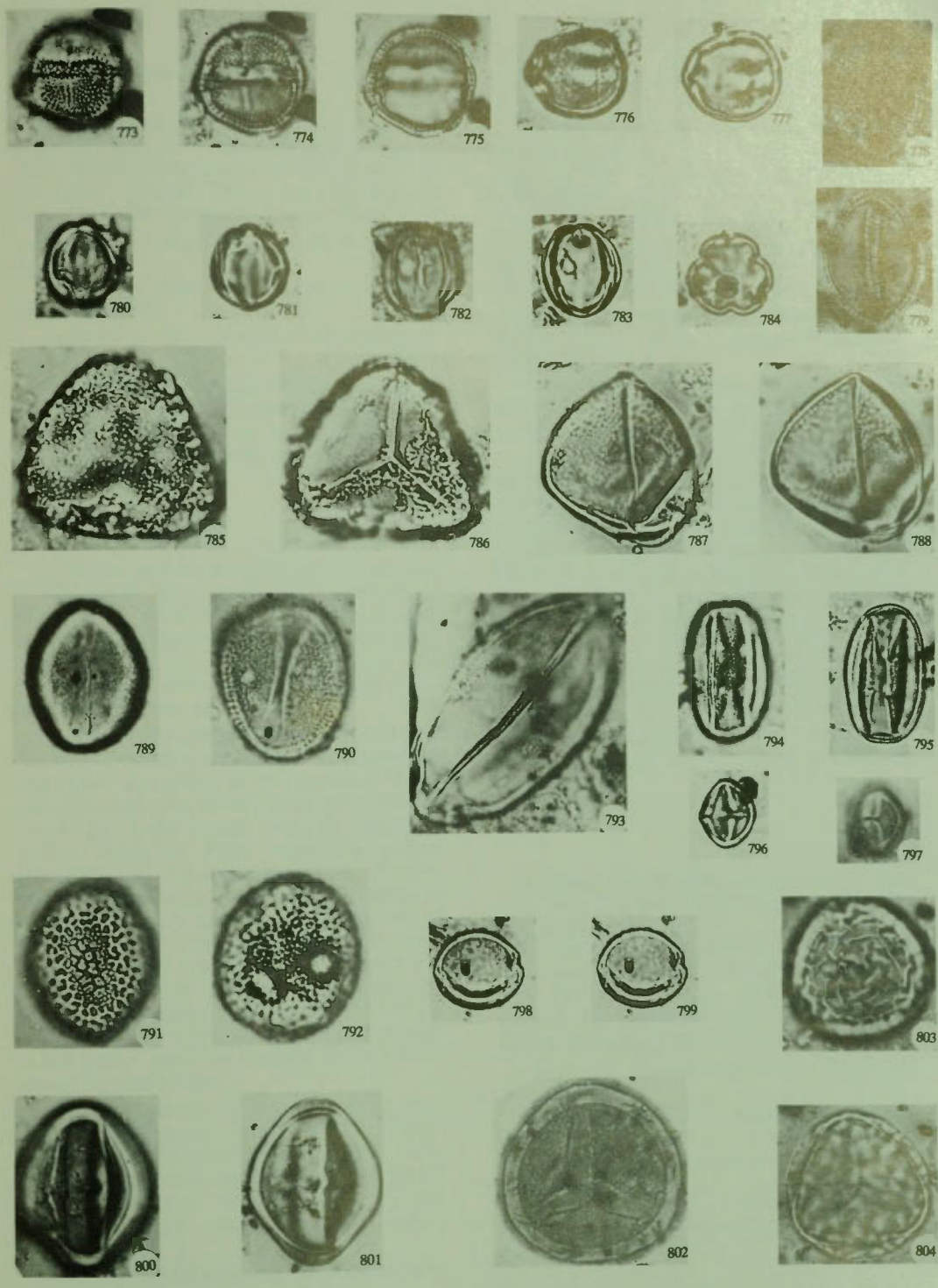


PLATE 43. Fossil pollens from Kalutara (Sri Lanka): 773–777, x 1000, *Rhizophoraceae*; 778–779, x 1000, *Oncosperma tigillarium*; 780–784, x 1000, *Lumnitzera sp.*; 785–788, x 1000, *Acrostichum aureum*; 789–792, x 1000, *Areca ssp.*; 793, x 1000, *Cocos nucifera*; 794–795, x 1000, *Cassia sp.*; 796–797, x 1000, *Elaeocarpus sp.*; 798–799, x 1000, *Ficus sp.*; 800–801, x 1000, *Ammonnia sp.*; 802, x 1000, *Isoetes sp.*; 803–804, x 1000, *Lycopodium cernuum*.

Malaysia (Johore)

Near Pekan Nanas (Johore state), Haseldonckx (1977) has brought to light a Holocene vegetation succession in relation to sea level changes. Three main ecological phases have been reconstructed as follows:

- a riparian fringe forest at the bottom of the core;
- an open swamp vegetation with mangrove influence;
- a marginal peat swamp with river bank vegetation.

Rhizophoraceae pollen remains a constant background feature throughout the sequence and this is considered as an indication that mangroves were in close proximity to the depositional site.

Borneo

Anderson and Muller (1975) have studied a Holocene peat from NW Borneo at Marudi. At around 4270 BP, the profile starts on a mangrove sediment because of the abundance of *Rhizophora*, *Nypa* and *Oncosperma*. Then succession proceeded from mangrove to peat swamp.

Further south, another palynological study has been carried out on the development and vegetation dynamics of an extensive Holocene lowland peat swamp from the Sebangu River in Kalimantan Tengah (Morley, 1981). Brackish water mangrove pollen belonging to *Rhizophora*, *Nypa*, *Brownlowia*, *Oncosperma*, *Acanthus* and spores of *Acrostichum* were found in the lower half of the profile. Their presence implies a considerable coastal advance as at present the coastline is 80 km further south. Since the amount of mangrove pollen is rather low, it is likely that they were not produced exactly at the pollen site, but brought from a local source by tidal action.

A continuously cored borewell, the MISEDOR project, about 650 m deep, located in the Mahakam delta (East Kalimantan), has been extensively studied. From the palynological investigations of this drilling, Caratini and Tissot (in press) deduce:

- the perenniality of the deltaic environment of the site from the Upper Pliocene to the present;
- a great diversity of the environmental conditions with a constant shifting of the shoreline due to the combined effects of the regression-erosion-transgression-progradation, within the delta.

The sedimentary sequence from the period of maximum cooling, at about 18,000 BP up to now, can be followed with great accuracy with the paleoenvironmental reconstruction of the vegetation near the MISEDOR drilling site:

- about 18,000 BP: low sea level; the site was located within a swamp forest; no mangrove elements were recorded;
- from 18,000 BP to 5000 BP: rising sea level; because of the landward shift of the shoreline, the site was successively surrounded by a back-mangrove vegetation, then the mangrove forest and a marine environment marking maximum transgression. With the progradation and edification of the delta, the shoreline shifted seawards in the reverse direction to that of the previous movement, and the MISEDOR site which was earlier occupied by the mangrove now stands in the back-mangrove *Nypa* plain.

Hence MISEDOR provides a clear example of a transgressive sequence followed by progradation.

Java

A recent survey of the mangroves of Java and Bali has been published by Sukardjo and Sutomo (1982).

In the region of Jakarta, Blasco (1982) described a transect in the Tji Tarum delta (Fig. 12). In the same area, Polhaupessy (1981) has demonstrated the following Upper Quaternary succession:

- first a *Rhizophoraceae* dominated mangrove;
- then *Rhizophora*, *Avicennia*, *Sonneratia*;
- *Rhizophora*, *Avicennia*, *Sonneratia*, *Nypa*;
- and lastly fresh water swamp with Cyperaceae, *Typha*, *Nymphaea* in the upper part of the core.

In Central Java, pollen analyses of Pliocene and Pleistocene sediments have yielded for the most part, the remains of mammals and hominids; Sangiran, in Central Java, may be cited as one of the more important sites (SEMAH, 1982).

The aim of this research is to reconstruct the vegetation and its evolution at the time of the island's colonisation by vertebrates and man, as well as to obtain information on the nature and evolution of the climate.

This study has brought to light the presence of mangrove pollen in a large number of the stratigraphic sections sampled. Several characteristic genera have been recorded, some of the important ones being those belonging to Rhizophoraceae (including several species of *Rhizophora*), Sonneratiaceae (among its species *Sonneratia caseolaris* has been consistently identified), *Excoecaria agallocha, Avicennia, Nypa fruticans, Acanthus ilicifolius, Clerodendrum*, etc.

Qualitative and quantitative analyses of these pollen types have enabled us to show the existence of a fossil shore-line. By studying the evolution it is possible to follow the shifting in the shore-line and the phenomenon of the island's emergence conditioning the eventual colonisation of the land by man and animals.

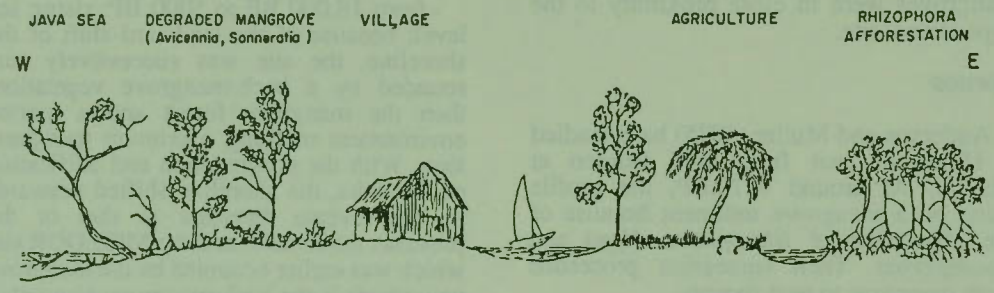
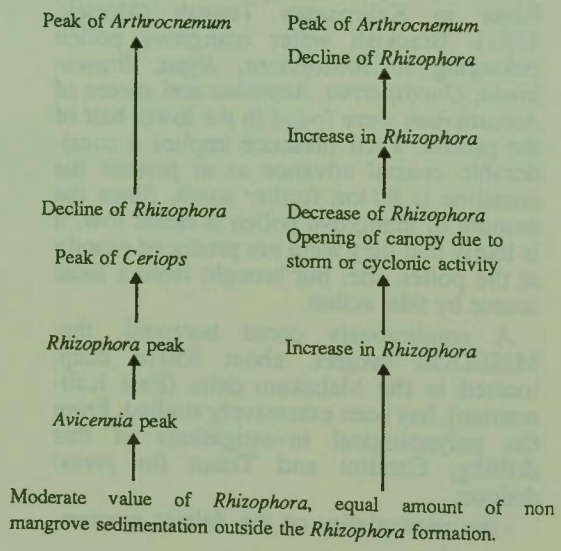


Fig. 12. Transect across a mangrove of Java, Tji Tarum delta (from Blasco, 1982).
The mangrove vegetation is totally disturbed by human activity.

AUSTRALIA

The recent mangrove forests of Australia are among the best known of the world (Clough, 1982). Some data are now available on their Holocene history.

To reconstruct the mangrove evolution on a prograded shore, Grindrod (1985) examined two core samples collected in North Queensland. Pollen analysis of a core sequence from bare high tide flats (Fig. 13) and another from a site immediately landward of a major long low ridge or "chenier" have provided a comparison of mangrove successions which have proceeded with or without interruption of a major chenier building event. The fossil pollen sequences are as follows:


Peak of Arthrocnemum
Decline of Rhizophora
Peak of Ceriops
Rhizophora peak
Avicennia peak
Peak of Arthrocnemum
Decline of Rhizophora
Increase in Rhizophora
Decrease of Rhizophora
Opening of canopy due to storm or cyclonic activity
Increase in Rhizophora
Moderate value of Rhizophora, equal amount of non mangrove sedimentation outside the Rhizophora formation.

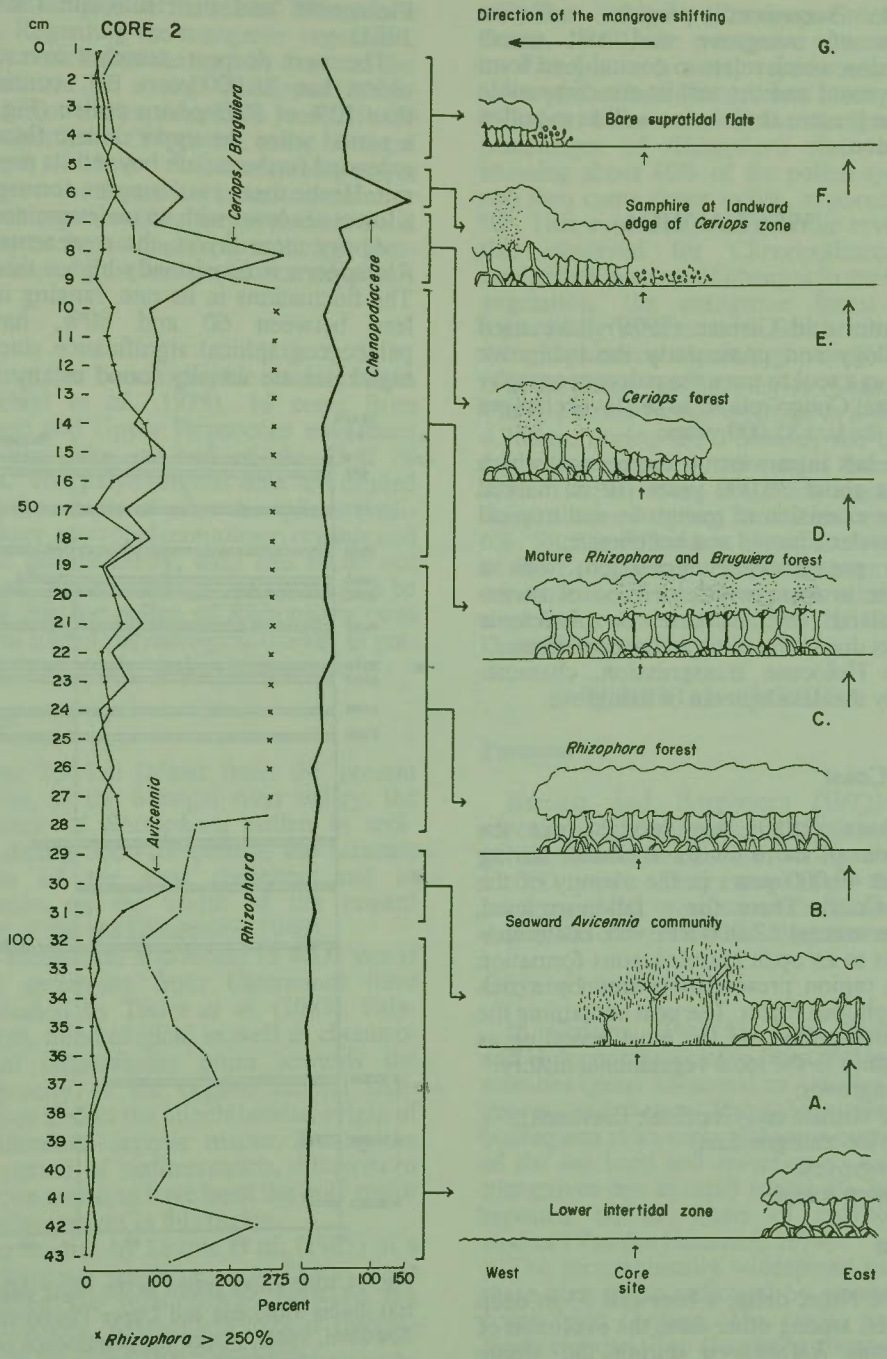


Fig. 13. Major trends of mangrove pollen representation and suggested corresponding vegetation changes near the site, North Queensland, Australia (from Grindrod, 1985).

These sequences provide sufficient records of mangrove and salt marsh succession which relate to coastal land form development and the results are compatible with the present zonation as well as to pollen deposition.

WEST AFRICA

Congo

Caratini and Giresse (1979) have used palynology and particularly the mangrove pollen as a tool to trace the palaeogeography of coastal Congo related to sea level changes during the last 35,000 years:

- the last intra-würm transgression which ends at about 30,000 years BP is marked with an extension of mangrove and tropical forest under a humid and hot climate;
- the pre-Holocene regression, with a decrease in mangrove, extension of savannas inland and increase in planktonic biomass due to the more active upwelling;
- the Holocene transgression, characterized by the development of mangrove.

Ivory Coast

Fredoux (1980) has brought out the variations of shore lines and climate during the past 40,000 years in the vicinity of the Ivory Coast. There the fall in sea level, –110 m around 17,000 BP, was contemporaneous to an open graminaceous formation in this region presently covered by a rich ombrophilous forest. The peat containing the mangrove pollen are the most revealing as they testify to the local vegetational history:

- mangroves;
- arid climate and Graminae (Savanna);
- marine transgression;
- mangroves;
- swamp forest.

Nigeria

In the Niger delta, a borewell 35 m deep provides, among other data, the evolution of the genus *Rhizophora* during the Upper Pleistocene and the Holocene (Sowumni, 1981).

The two deepest samples investigated, older than 35,000 years BP, contain less than 10% of *Rhizophora* pollen (Fig. 14) at a period when the upper deltaic flood plain extended further south beyond its present limit. Hence these two samples correspond to a lower sea level with an undetermined age.

Above these layers, the representation of *Rhizophora* is consistently higher than 50%. The fluctuations in its rate, ranging more or less between 60 and 80%, have no palaeogeographical significance since such high rates are usually found in any surface

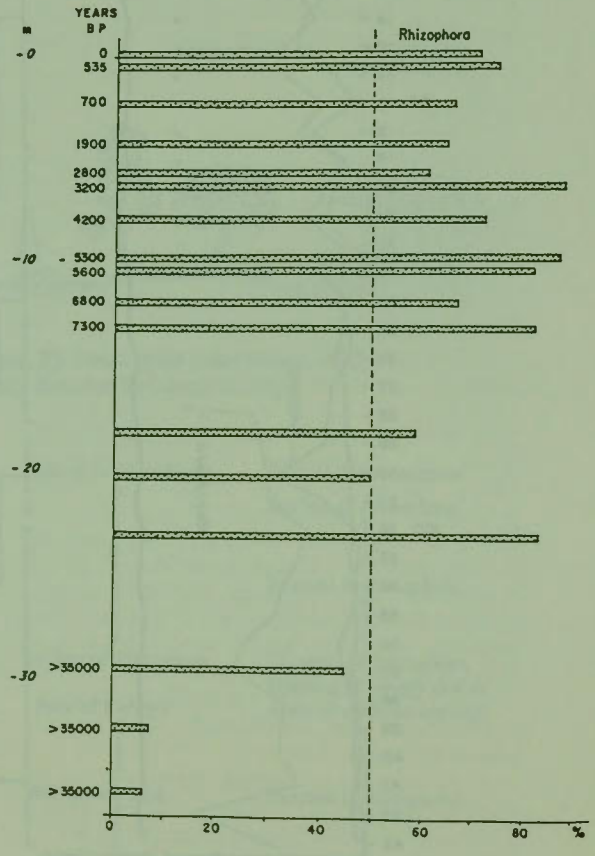


Fig. 14. Rhizophora pollen in the Niger delta (Nigeria) during Holocene and Upper Pleistocene (from Sowunmi, 1981). Notice the permanence of Rhizophora representation from about 22 m to the top.

sediment samples in the recent *Rhizophora* forests. Regarding the mangrove vegetation, the only conclusion that can be drawn is the establishment of a well developed *Rhizophora* forest earlier than 7300 years BP, the oldest significant C^{14} dating being obtained at a depth of 13 m. It is remarkable that in this region the forest has remained more or less unchanged, without any disturbance and this may be due to the feeble anthropic pressure because of the low population density.

Benin

During the oceanographic cruise Benin (Klingebiel *et al.*, 1975), 14 cores from Holocene and Upper Pleistocene have been taken from the sea-bed of the Gulf of Guinea. The palynological data are diluted among the results of other disciplines (sedimentology, micropalaeontology, organic and mineral geochemistry, etc.) and so do not stand out. Nevertheless, it can once again be noticed that the pollen of *Rhizophora* was the most useful palynological marker to precise the stratigraphy and palaeogeography.

Senegal

About 250 km inland from the present shoreline, in the Senegal river valley, the occurrence of *Rhizophora* pollen in sediments dating 5500 BP permits the accurate location of the past shoreline and to emphasize on the width of the inward shifting of the sea (Assemien, 1969).

The recent and sub-recent (± 4000 years) coastal sediments from Casamance have been studied by Tissot *et al.* (1983). Palynological, mineralogical as well as chemico-physical palaeofacies point towards the homogeneity of the organo-mineral sedimentation and to the allochthonous origin of the sedimental organic matter. During the entire period of sedimentation, *Rhizophora* mangrove seems to have been the only major vegetation present in this region.

Other studies by Lezine *et al.* (1985) of a Late Holocene sequence, near Dakar, have established the relationships between sea level changes, palaeohydrological fluctuations and the mangrove vegetation.

In three cores located on the slope offshore Senegal (Rossignol–Strick and Duzer, 1979), the mangrove characterized by *Rhizophora* is rarely represented during most of the Late Pleistocene. From 12,000 BP, just before the Holocene limit, the percentages of *Rhizophora* rise rapidly, attaining about 40% of the pollen spectrum and then come down to 6%, at about 7,000 BP. This evolution, which is the reverse of that observed for Chenopodiaceae, is interpreted in terms of changes in the coastal vegetation, the mangrove forest being replaced by sebkhas with *Salicornia* during the arid phase corresponding to the Würm.

In the DSDP site 367, leg 41 (Sittler *et al.*, 1980), located further offshore at a depth of 4,700 m, during the Pliocene, the percentage of mangrove pollen ranges from 11 to 27%. These values are much higher than those obtained during the Pleistocene: 2 to 6%. Such a difference, regarded as a result of the rising sea level, could rather be the consequence of the falling sea level which is a global event occurring at the Tertiary-Quaternary boundary.

TROPICAL AMERICA

Panama

Bartlett and Barghoorn (1973) have reconstructed the phytogeographic evolution of the Panama isthmus during the past 12,000 years. They emphasize that the mangrove was more equatorially restricted during the cold period than they are today.

Guyana and Surinam

In Guyana (Fig. 15), Late Pleistocene and Holocene succession from dryland communities (grass savannas) to *Avicennia* mangroves, and then to *Rhizophora* mangroves consequent to an early Holocene eustatic rise of the sea level and reversion to *Avicennia* mangroves due to rapid silting (?), has been reported on the basis of palynological studies (Van der Hammen, 1974).

The geographically widespread nature of these changes is indicated by several other cores from Guyana. The cyclic nature of these changes has also been demonstrated from the pollen analysis of a core from Surinam (Wijmstra, 1971).

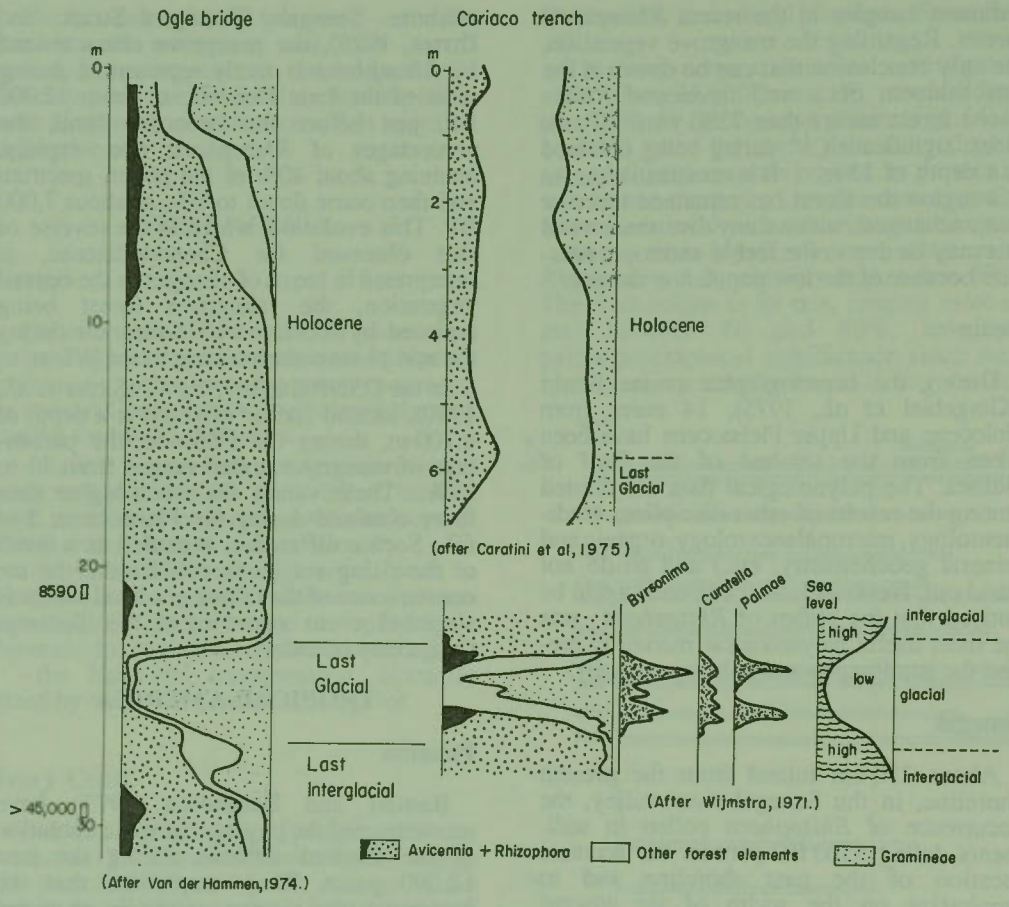


Fig. 15. Evolution of coastal vegetation in Guyana, Surinam and Venezuela during Late Pleistocene and Holocene showing the relationships between sea level and pollen spectra: the transgressive sequences are characterized by the high values of Rhizophora pollen.

Venezuela

Classical studies of recent Orinoco delta sediments by Muller (1959) have provided the palynological basis for tracing the depositional history of the mangroves.

In the Cariaco trench (Fig. 15), the Holocene sediments yielded kerogen which is mainly composed of marine amorphous organic matter. The perfect state of preservation of this organic matter implies that it must be autochthonous. The pollen and spores present in the organic matter correspond to the flora of the Orinoco basin (including mangroves) which is probably an indication that the Guyana current carried these pollen and spores to the Cariaco trench (Caratini *et al.*, 1975).

Florida

The almost continous geological evidence of mangroves in Florida since 3000-4000 years indicates that *Avicennia* has probably been present in the northern Gulf region throughout that period (Hoffmeister and Multer, 1965).

Other palynological data on the mangrove history are provided by peat formations (Riegel ,1965).

TERTIARY RECORDS OF MANGROVE TAXA

In their extensive palynological studies on the Tertiary of tropical areas, Germeraad *et al.* (1968) have reported the stratigraphic range and geographic distribution of mangrove pollen taxa in some areas such as the Carribbean region, Venezuela, Nigeria. Their conclusions on these sedimentary basins are still valid to date.

New data are now available in other countries. A survey of the records of the fossil mangrove pollen taxa in these regions is given below.

India

The following picture of fossil history emerges from our survey of the mangrove taxa represented in the fossil pollen records from the sedimentary basins of the Indian subcontinent. *Nypa* can be traced back up to Upper Cretaceous, Rhizophoraceae up to Middle Eocene, *Avicennia* and *Aegialitis* up to Miocene and *Sonneratia* with certitude up to Lower Miocene.

Fossil records

Bengal Basin (Baksi and Deb, 1980)

Nypa	Upper Cretaceous-Recent

Cauvery Basin

Karaikal (Venkatachala and Rawat, 1972, 1973)

Nypa	Palaeocene-Middle Eocene
Rhizophoraceae	Middle Eocene-Miocene

Mannargudi (Venkatachala and Rawat, 1972, 1973)

Nypa	Lower-Middle Eocene
Rhizophoraceae	Middle Eocene

Madanam (Venkatachala and Rawat, 1972, 1973)

Nypa	Middle Eocene
Rhizophoraceae	Middle Eocene-Middle Miocene

Neyveli (Ramanujam and Reddy, 1984)

Rhizophoraceae	Miocene
Avicennia:	Miocene

Warkali (Thanikaimoni *et al.*, 1984)

Aegialitis	Miocene

Ratnagiri (Kulkarni and Phadtare, 1981)

Nypa	Miocene

Cambay Basin — Lower Eocene (Venkatachala, 1972)

Nypa	Lower Eocene (Mathur and Chowdhary, 1977)
Rhizophoraceae	Lower Eocene (Venkatachala and Chowdhary, 1977)
Sonneratia:	Lower Eocene (*ibid.*)

Himachal Pradesh (Mathur, 1984)

Nypa:	Eocene
Rhizophora:	Lower-Middle Eocene
Sonneratia:	Lower-Middle Eocene

Kutch Basin (Venkatachala and Kar, 1969; Kar, 1985)

Nypa	Palaeocene-Oligocene
Rhizophoraceae	Palaeocene-Oligocene
Sonneratia	Eocene

Europe

The distribution and palaeogeographic value (Fig. 16) of *Nypa* pollen in the Eocene of Europe has been studied by Ollivier-Pierre and Caratini (1984). According to Collinson (1983), the occurrence of *Nypa* fruits in London Clay is an indication of the seaward deposition of mangrove debris. Core mangrove species are rarer than the back-mangrove genus *Nypa* in London Clay, but Rhizophoraceae are represented by seedlings of *Ceriops* and *Palaeobruguiera*. The absence of Rhizophoraceae pollen from London Clay seems to support the paucity of this family in Eocene types (Wilkinson, 1981, 1983).

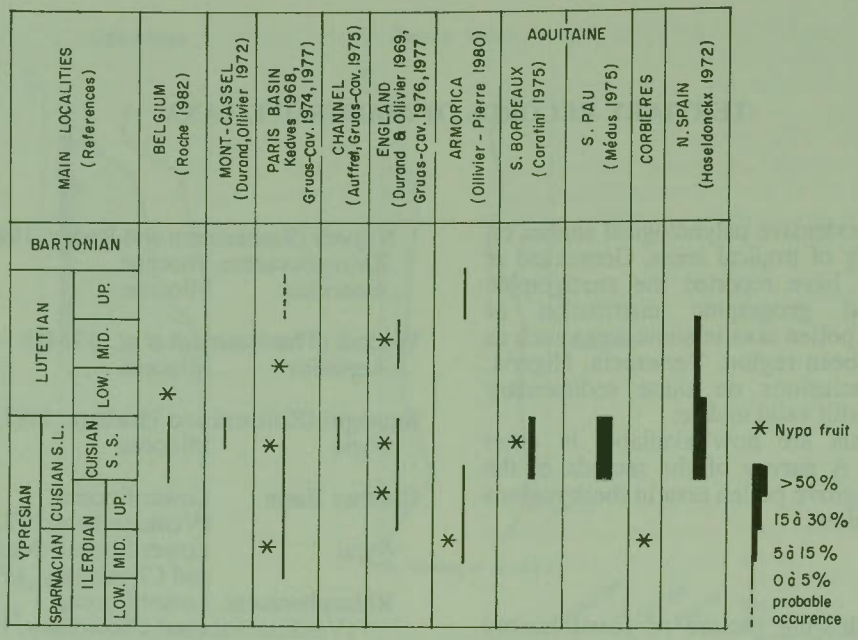


Fig. 16. Range and geographical distribution of Nypa during Eocene in W Europe (from Ollivier-Pierre and Caratini, 1984).

In France, Gruas-Cavagnetto (in press) has reported pollen grains of *Bruguiera*, *Ceriops* associated with *Nypa* in the Ypresian (Eocene) of Soissonnais (France). She has recognized another type of mangrove with *Avicennia* during the Middle Eocene (Auversian) in Manche. From these mangrove taxa, as well as other tropical taxa, the evolution of the palaeoclimate during the Paleogene has been reconstructed by Ollivier-Pierre *et al.* (in press).

During the Lower and Middle Miocene, some occurrences of *Avicennia* pollen. (Bessedik, 1981 ; 1985) on the north western mediterranean shores suggest the development of mangrove in this region.

Burma

Some aspects of the present distribution pattern of mangrove vegetation in Burma have been studied in several sites along the coast (Myint and Soe, 1985). Twenty one species of mangroves were observed. Among the important species are *Avicennia officinalis*, *A. elliptica*, *Sonneratia griffithii*, *Ceriops decandra*, *Dalbergia spinosa* and *Excoecaria agallocha*.

According to Reimann and Aye Thaung (1981), the Middle Miocene beds of the South Western part of Chindwin Basin in Kalemyo and Kalewa, were deposited in coastal, marine, brackish, shallow water zones. To support their contention, the authors have drawn attention to the pollen of *Rhizophora* and *Sonneratia* as well as the Microforaminifera and Histrichosphaerids found in the samples. They feel that the presence of *Florschuetzia levipoli* (*Sonneratia* pollen) in the sediment is an index of Miocene age.

Borneo

In his palynological studies on the history of the mangrove vegetation of Borneo, Muller (1964) stressed the fact that the fossil pollen types attributed to mangroves match well in detail with those of the extant mangrove taxa. They are associated in both

recent and fossil sediments of Borneo; there is an unbroken succession of mangrove pollen from the Lower Tertiary upwards to the recent. The stratigraphic ranges of mangrove pollen types in Borneo as updated by Morley (1978) are as follows:

Nypa	Eocene up to present
Brownlowia type	Eocene up to present
Rhizophora type	Oligocene up to present
Sonneratia alba type	Miocene up to present
S. caseolaris type	Miocene up to present
Avicennia type	Middle Miocene up to present
Aegialitis	Middle Miocene up to present

Barré-de Cruz (1982) studied a period as old as the Upper Miocene up to now (Fig. 17) from the Tunu 1 drilling in the Mahakam delta. She has confirmed the ranges of the main markers and gives the following palaeogeographical results:

- perenniality of the deltaic conditions;
- diversity of the palaeoenvironments within this delta.

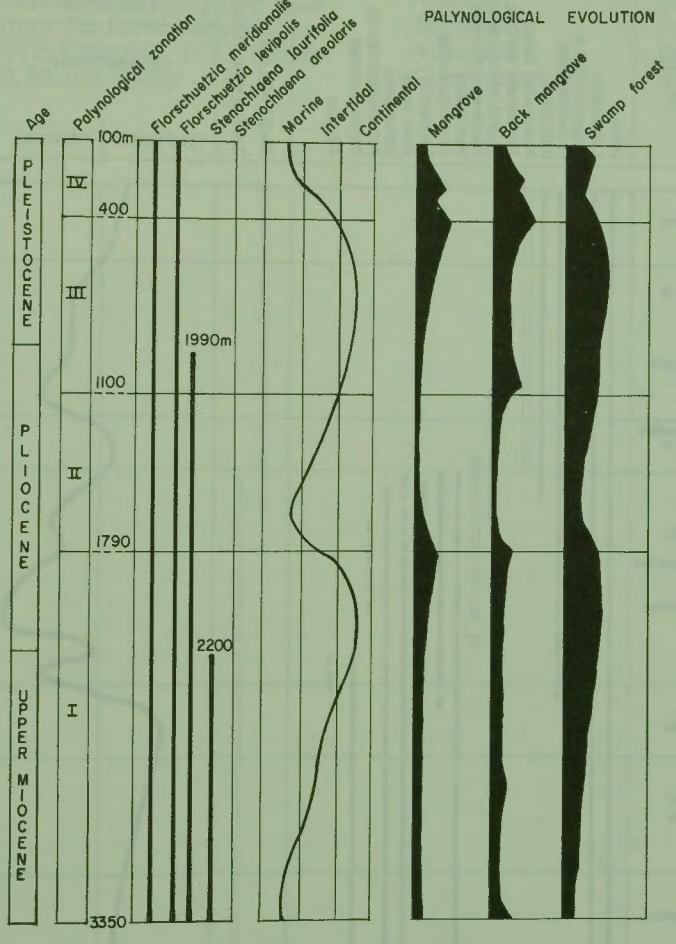


Fig. 17. Stratigraphical ranges, palaeogeography and palynological evolution of the site of Tunu 1 drilling, Mahakam delta, Kalimantan, Indonesia (from Barré-de Cruz, 1982).

China

In the coastal areas of Fujian and Guangdong, mangrove forests seem to have existed during the Tertiary period (Wang, 1984). It is noteworthy that in Beibu (South China Sea), Barré-de Cruz (1982) has recorded *Florschuetzia levipoli*, *Dacrydium* and *Stenochlaena laurifolia* (Fig. 18). The first two taxa have Miocene-Pliocene range whereas the last one does not extend beyond Upper Miocene. In Beibu, the simultaneous occurrence of Dinoflagellate cysts and mangrove taxa during the Miocene suggests that the site of study was near the sea or in a marine environment.

In the northern part of South China Sea (Sun and Li, 1984), *Florschuetzia* appeared in the Late Eocene and flourished in the Miocene. It evolved quickly both here as well as in SE Asia. Many other pollen types were common to both areas, but this area lacked the most evolved type, *F. meridionalis*, which appeared in the Late Miocene in SE Asia.

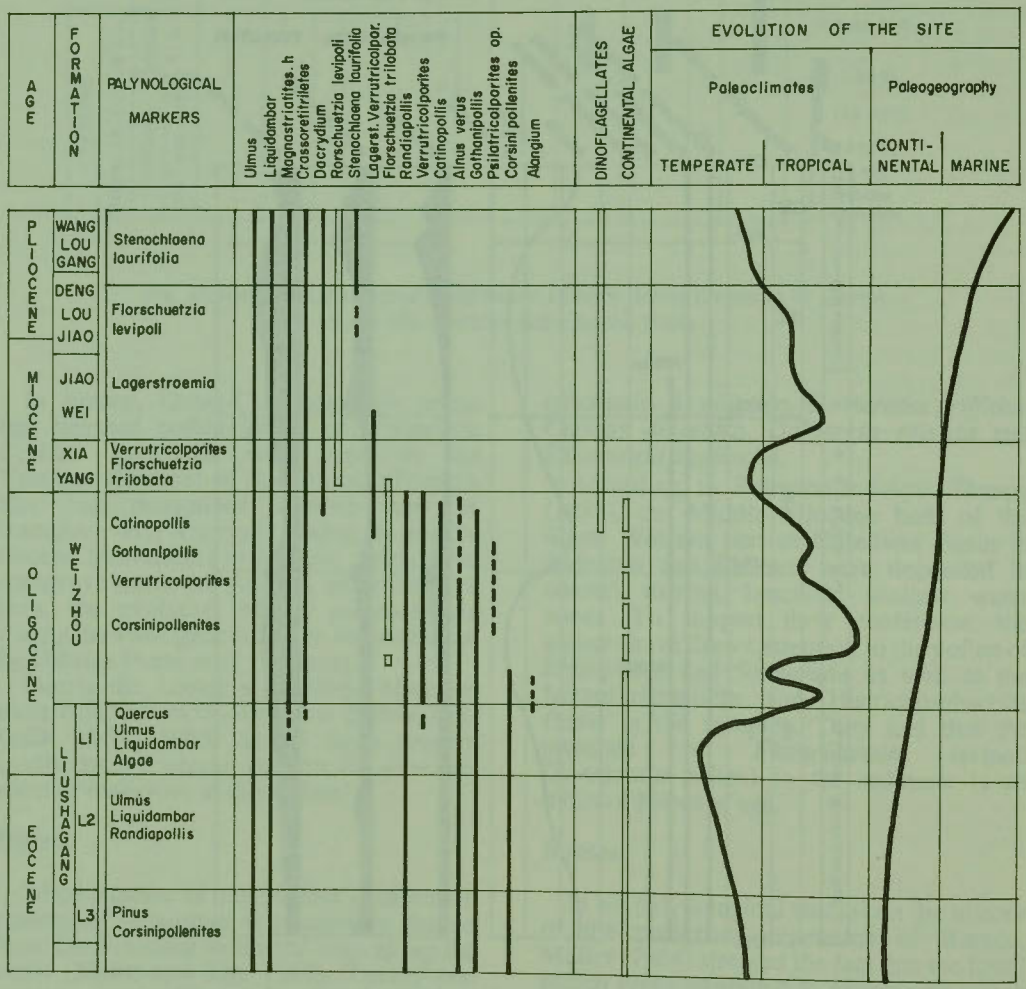


Fig. 18. Beibu borewell, China Sea: Palynological zonation and palaeogeographical evolution of the site (from Barré-de Cruz, 1982).

Japan

The available fossil evidence indicates that *Bruguiera* (Rhizophoraceae), *Sonneratia* (Sonneratiaceae), *Excoecaria* (Euphorbiaceae) as well as the *Telescopium-Geloina* biocœnosis characteristic of mangroves existed during Middle Miocene of South West and Central Japan. After 15 million years, the tropical and mangrove swamp elements disappeared rapidly (Yamanoi *et al.*, 1980; Tsuda *et al.*, 1984).

Australia

Pollen of the following mangrove taxa were reported from the fossil beds of Australia (Hekel, 1972; Churchill, 1973; Stover and Evans, 1973; Martin, 1982):

Rhizophoraceae (*Zonocostites ramonae*)	Palaeocene-Pliocene

Rhizophora stylosa is now found in Western Australia (Semeniuk *et al.*, 1978).

Brownlowia type	from Eocene
Nypa (*Spinizonocolpites prominatus*)	Late Eocene-Lower Miocene
Sonneratia	from Oligocene

Churchill (1973) reported *Sonneratia* pollen in the Eocene of Western Australia but since the exine structure and sculpture are not described in detail, the identification cannot be accepted.

Acanthus	from Late Miocene
Aegialitis	from Late Miocene
Avicennia	from Late Miocene
Camptostemon	from Late Miocene

EVOLUTION OF MANGROVE TAXA FROM UPPER CRETACEOUS TO RECENT

Several extinct pollen are considered to be characteristic of a mangrove vegetation. Their stratigraphical ranges are given in fig. 19. However, since no definite argument can be provided, taxa such as *Echiperiporites trianguliformis* and *Proxapertites* will not be retained in this survey of fossil records of the pollen attributed to mangrove taxa.

A well documented palaeoecological review of fossil mangrove pollen and spore taxa, specially for the Early Tertiary period, is found in Frederiksen (1985).

ARECACEAE

Nypa

This genus seems to have had a vast fossil distribution. Pollen comparable to that of *Nypa* are reported from the Upper Cretaceous and Tertiary of the Carribbean, Venezuela, Nigeria, Borneo and India. The fossil pollen grains are described under the morphological name *Spinizonocolpites* Muller 1968. Several species have been considered within this genus but the distinction between them is not clear since all the intermediates can be found. Nevertheless, it has been noticed (Germeraad *et al.*, 1968) that in the Upper Cretaceous-Paleocene sediments, *S. baculatus* Muller 1968 is the dominant form, while later *S. echinatus* Muller 1968 is found exclusively.

Its extinction at the Eocene-Oligocene boundary in Central America and West Africa is approximately contemporaneous with a widespread increase in the incidence of mottled shales indicating a climatic change with a more pronounced seasonal rainfall. It is conceivable that such a change could have caused *Nypa* to disappear since it is now mainly restricted to the ever wet tropics in the Indo-Malaysian area (Germeraad *et al.*, 1968).

In Europe *Nypa* left its traces in the Lower-Middle Eocene sediments. Its distribution has been clearly elucidated by Haseldonckx (1972); its climatic (Muller 1980) and palaeogeographic (Ollivier-Pierre and Caratini, 1984) implications have been deduced (Fig. 16).

In Australia, the stratigraphic range of this genus is from Palaeocene to Middle Miocene. According to Muller (1980), its disappearance may be due to the movement of Australia to a more arid climatic belt and not to a decrease in temperature.

AVICENNIACEAE

Avicennia

The earliest occurrence of *Avicennia* is in the Lower Miocene in Marshall Islands in the West Pacific (Leopold, 1969). It has been recorded in the Upper Miocene of NW Borneo (Anderson & Muller, 1975) and has been traced up to the Pliocene of Guyana (Wijmstra, 1971). In India, it has been reported from the Miocene (Ramanujam and Reddy, 1984). In Europe, several pollen grains of *Avicennia* may have been identified from Paleogene (Gruas-Cavagnetto *et al.*, in press) and Miocene (Bessedik, 1981).

BOMBACACEAE

Camptostemon pollen type was first recorded from the Lower Miocene of NW Borneo (Muller, 1970).

Malvacearumpollis papuensis Khan 1976 which has equatorial apertures, reported from the Upper Miocene of Papua,is probably *Camptostemon* pollen (Muller, 1981).

PELLICIERACEAE

Jimenez (1984) tried to explain the present restricted distribution of this mangrove

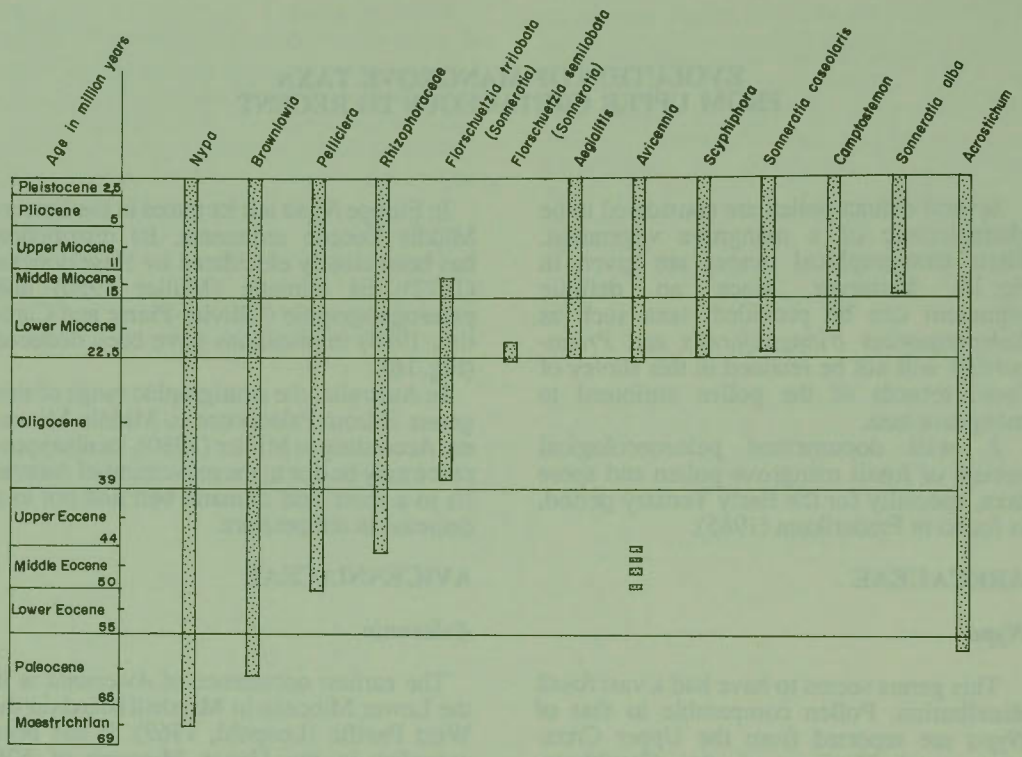


Fig. 19. Range of mangrove pollen and spore taxa.

genus which has only one species *Pelliciera rhizophorae* in Central and Northern South America although it was widespread in the Carribbean Tertiary deposits (Graham, 1985).

Fossil pollen records

Pelliciera

Graham (1977) Lower-Middle Eocene, Jamaica

Langenheim *et al.* (1967) Oligo-Miocene, Mexico.

Psilatricolporites crassus V. der H. et Wijm. 1964 = (*Verrutricolporites crassus*)

Pares Regali *et al.* (1974 a & b) Middle Eocene to Miocene, Brasil

Salard-Cheboldaeff (1976) Oligocene, Cameroon

Chateauneuf (1980): Middle and Upper Eocene, Paris Basin

PLUMBAGINACEAE

Aegialitis

Pollen comparable to *Aegialitis* have been reported from the Miocene to Pliocene of Borneo (Morley, 1978) where this genus is now absent. According to Muller (1972), the discontinuity in its present distribution may be due to its failure to adapt itself to drier climates.

In India, it has recently been reported from the Miocene of Warkalli, in the coastal region of Kerala (Thanikaimoni *et al.*, 1984) under the name *Warkallipollenites erdtmanii* Ramanujam & Rao, 1984.

RHIZOPHORACEAE

The earliest occurrence of this family, with the morphological genus *Zonocostites* is in the Eocene of the Carribbean region,

India and Borneo. It gradually becomes a dominant element in the Miocene-Pliocene mangrove communities. In Queensland, its earliest report is from Oligocene (Martin, 1982). In Nigeria, its first occurrence and that too with sudden abundance is in the Lower Miocene.

According to Muller and Caratini (1977), this family must have originated in the Eocene of SE Asia with inland relatives such as *Anisophylla* and *Carallia* and extended eastwards via transpacific land bridge to tropical South America. It seems to have reached the Carribbean region before the origin of the Panama Isthmus and from there crossed the Atlantic to settle along the west coast of Africa during Early Miocene.

According to Van Steenis (1962), the lack of *Rhizophora* species common to east and west coasts of Africa is due to the colder climate of South Africa. But Germeraad *et al.* (1968) have suggested that by the time the present Indo-Malaysian species of *Rhizophora* had developed and started to extend their range *viz.* in the Oligocene-Miocene period, the Tethys connection to the Atlantic Ocean had either already become closed or was situated too far north in a cooler climatic zone.

Regarding the occurrence of Rhizophoraceae fossils in London Clay, Germeraad *et al.* (1968) expressed the view that during the Eocene the tropical belt extended to higher latitudes. Before the compression and overthrusting of the ancient Tethys sediments that accompanied the origin of the Alps, the Eocene southern shores could have been situated further south than its present location.

According to Gruas-Cavagnetto (in press), the pollen taxa *Bruguiera* and *Ceriops* would have been recorded in the Ypresian of France.

RUBIACEAE

Scyphiphora type pollen has been recorded by Leopold (1969) and compared to *S. hydrophyllacea* from the Lower Miocene of the Marshall Islands in the West Pacific.

SONNERATIACEAE

Sonneratia

According to Muller (1985), *Sonneratia* is an Asian genus. The Eocene ancestors of this taxa may have been plants from the Tethys shore adapted to pollination by fruit eating bats which appear in fossil records about the same time as the first pollen record. The increase in pollen production and in gregariousness are probably caused by adaptation to bat pollination. Muller (1968) has suggested the following evolutionnary sequence:

Lagerstroemia (insect pollination)
→ *Florschuetzia trilobata*
→ *Sonneratia* (bat pollination).

The generic changes anticipated in some of the recent polulations of *Sonneratia alata* and *S. caseolaris* could conceivably lead to the origin of a new species which, in order to be evolutionally successful, should also change its ecology so that it could invade a new niche or replace its parent, as has probably happened in the Early Miocene (Muller, 1985).

Sonneratia pollen and its ancestors *Florschuetzia* constitute a phylogenetic series which provides the best stratigraphical markers of the Oligocene and Neogene of South East Asia (Germeraad *et al.*, 1968).

TILIACEAE

Brownlowia

In Borneo this back mangrove as well as swamp forest genus occupied the same ecological niche throughout the Tertiary (Muller, 1964, 1968, 1981; Barré-de Cruz, 1982). In India, pollen grains comparable to *Brownlowia* have been reported under the name *Lacrimapollis* from the Miocene of the Cauvery delta and the Miocene-Pliocene sediments of Tripura (Thanikaimoni *et al.*, 1984). In Australia (Harris, 1965; Stover and Evans, 1973) the same morphological type named *Tiliaepollenites notabilis* Harris 1965 ranges in the Eocene.

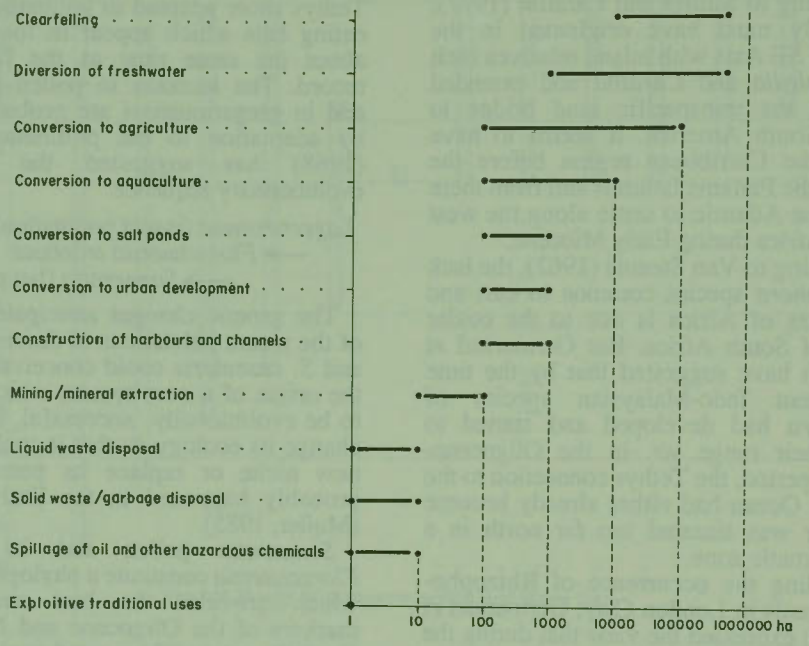


Fig. 20. Scale of human impact on world mangrove vegetation (data from Saenger *et al.*, 1983).

CONCLUSION

The volume and diversity of palynological studies devoted to mangroves can be explained by some of the most original characteristics of this ecosystem *viz:* its location at the ocean-continent interface in tropical regions and in their vicinity. These fundamental aspects constitute the basic criteria for the interpretations put forward by palynologists. Depending on their field of specialization, researchers analyze the data and attempt to reconstitute, explain or show the changes in the course of rivers, variations in the sea level, climatic fluctuations that occured over the course of time, etc.

The lines of research on Tertiary sediments are different from those of the Quaternary. In Quaternary research the method followed in most cases is to reconstruct the evolution of the mangrove vegetation. The interpretations and hypotheses are derived from an understanding of this evolution. As regards the Tertiary and Upper Cretaceous, the pollen and spores of mangroves are no longer considered as elements of a population, but as isolated individuals constituting stratigraphic or palaeogeographic markers. Their frequency in marine and coastal sediments is due to the fact that mangrove pollen are liberated directly into the ocean where conditions are favourable (low oxidation) for their preservation and fossilization. Moreover, since mangrove forests are particularly abundant in deltaic zones which are well known for their organic matter deposits, palynologists devoted to oil research have since long considered the study of mangrove pollen and spores of potential interest. This is particularly true for *Rhizophora-Zonocostites,* the most familiar sporomorph taxon of the mangroves, as well as for *Sonneratia-Florschuetzia* recorded in south -east Asian region.

When the recent past, i.e. the last few centuries, is taken into consideration, palynology enables us to follow the evolution of mangrove vegetation and to better understand the present state of the ecosystem by locating it in its proper place during the course of evolution. In fact, because of the changing dynamism to which the mangroves are subjected, the present stage of the ecosystem cannot be properly explained if the time factor is not taken into consideration.

In the past, natural events such as the deterioration in climatic conditions or the shifts in the course of rivers may have locally affected the mangroves but their impact was not great when compared to the spate of destruction which has just begun with the (human) population explosion, particularly in Asia. For example, when rivers are dammed the mangroves receive less silt and fresh water. This increases the salinity, resulting in the death of the mangroves sooner or later. Man's impact on mangroves is striking (Saenger *et al.* 1983) and deserves to be taken seriously (Fig. 20).

As mangrove forests protect the coast from erosion and from the fury of tides and cyclones and as they contribute the much needed organic matter for the population of the fishes, shrimps and crabs of the tidal ecosystem and to some extend even of the sea, the role played by them is essential for the preservation of the entire ecosystem. Thus it is time that integrated multidisciplinary approaches, including palynology, are initiated with a view to use on sustained yield basis without causing destruction of these coastal regions and to launch educational campaign to protect and maintain them because *we need mangroves and not man made mangrove.*

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